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H.R. 3970, GREEN CHEMISTRY RESEARCH AND DEVELOPMENT ACT OF 2004

HEARING

BEFORE THE

COMMITTEE ON SCIENCE
HOUSE OF REPRESENTATIVES

ONE HUNDRED EIGHTH CONGRESS

SECOND SESSION

MARCH 17, 2004

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H.R. 3970, GREEN CHEMISTRY RESEARCH AND DEVELOPMENT ACT OF 2004

WEDNESDAY, MARCH 17, 2004

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE,
Washington, DC.

The Committee met, pursuant to call, at 10:00 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Sherwood L. Boehlert [Chairman of the Committee] presiding.

COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

H.R. 3970, the Green Chemistry Research and Development Act of 2004

Wednesday, March 17, 2004
10:00 a.m. – 12:00 p.m.
2318 Rayburn House Office Building (WEBCAST)

Witness List

Dr. Arden Bement
Acting Director
National Science Foundation

Dr. Paul Gilman
Assistant Administrator for Research and Development
Environmental Protection Agency

Dr. Berkeley Cue
Vice President of Pharmaceutical Sciences
Pfizer Global Research and Development

Mr. Steven Bradfield
Vice President of Environmental Development
Shaw Industries, Inc.

Dr. Edward Woodhouse
Associate Professor of Political Science, Department of Science & Technology Studies
Rensselaer Polytechnic Institute

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HEARING CHARTER

COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

H.R. 3970, Green Chemistry Research and Development Act of 2004

WEDNESDAY, MARCH 17, 2004
10:00 A.M.–12:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

1. Purpose

On Wednesday, March 17, 2004 the House Science Committee will hold a hearing to examine federal and industry green chemistry research and development (R&D) activities, and to receive testimony on H.R. 3970, the *Green Chemistry Research and Development Act of 2004.* This bill would authorize a federal green chemistry R&D program.

2. Witnesses

Dr. Arden Bement is the Acting Director of the National Science Foundation (NSF) while continuing in his position as the Director of the National Institute of Standards and Technology (NIST).

Dr. Paul Gilman is the Assistant Administrator for Research and Development at the Environmental Protection Agency (EPA). He also serves as the Agency's Science Advisor.

Dr. Berkeley Cue is Vice President of Pharmaceutical Sciences at Pfizer Global Research and Development. Pfizer, Inc. has established green chemistry teams at its facilities throughout the world, and won a 2002 Presidential Green Chemistry Challenge Award for the redesign of the sertraline manufacture process. Sertraline is the active ingredient in Zoloft, which is used widely in the U.S. to treat depression. The new process improves worker and environmental safety, reduces energy and water use, and doubles overall product yield.

Mr. Steven Bradfield is Vice President of Environmental Development at Shaw Industries. Shaw Industries won a 2003 Presidential Green Chemistry Challenge Award for the development of EcoWorx™ carpet tile. EcoWorx™ carpet tiles are made from low toxicity feedstocks and are recyclable.

Dr. Edward Woodhouse is Associate Professor of Political Science in the Department of Science & Technology Studies at Rensselaer Polytechnic Institute. Dr. Woodhouse studies the social aspects of technological decision-making.

3. Overarching Questions

- How has—and how can—effective application of green chemistry products and processes contributed to environmental protection and sustainability? What are the costs associated with using green chemistry products and processes?
- How has private industry benefited from, and contributed to, green chemistry breakthroughs? To what extent has private industry used green chemistry products and processes? What are the primary barriers to increased development and adoption of green chemistry products and processes, and how can these barriers be removed?
- What is the current status of the Federal Government's efforts in green chemistry R&D? Are expanded federal efforts and increased federal coordination in green chemistry warranted?
- Does H.R. 3970 establish a program that will result in greater R&D breakthroughs and increased adoption of green chemistry? How can the legislation be improved?

4. Brief Overview

- Green chemistry is the design of chemical products and processes that reduce or eliminate the use or generation of hazardous substances. Green chemistry is a form of pollution prevention—preventing pollution rather than treating emissions.

- A number of success stories have generated a great deal of excitement about the significant potential of green chemistry for environmental and economic benefit. Implementation of green chemistry at a Dow Chemical plant aimed at increasing efficiency and instituting more recycling is showing a 174 percent annual return on a one-time investment. However, even this highly touted example has not been repeated and adoption of green chemistry products and processes by industry has been limited. Barriers to greater adoption include a workforce unfamiliar with green chemistry, a lack of existing and demonstrated alternatives, the sometimes high capital costs of changing processes, a lack of regulatory drivers, and inertia.
- Federal support for green chemistry R&D has also been limited. The most notable effort is the joint-NSF/EPA Technology for a Sustainable Environment (TSE) program. The program, which includes, but is not limited to, green chemistry activities, awarded $11 million in R&D grants in fiscal years 2002–03. Other agencies such as the Department of Energy (DOE) and NIST also provide support for green chemistry.
- EPA also administers the Presidential Green Chemistry Challenge Awards Program to recognize advances in and to promote green chemistry. Since 1996, this program has made 40 awards to businesses and academics that develop technologies that incorporate the principles of green chemistry and that have or can be used by industry. Both Pfizer, Inc. and Shaw Industries have recently won this award.
- On March 16, 2004 Representative Phil Gingrey introduced H.R. 3970, the *Green Chemistry Research and Development Act of 2004.* This legislation would establish an Interagency Working Group to coordinate federal green chemistry R&D activities and facilitate adoption of green chemistry by the private sector. The bill would authorize funding for these activities (from within existing authorizations) at NSF, EPA, NIST, and DOE through fiscal year 2007.

5. Background

What is green chemistry?

Green chemistry is most commonly defined as chemistry and chemical engineering that involves the design of chemical products and processes that reduce or eliminate the use or generation of hazardous substances. It is sometimes characterized as "benign by design" to emphasize that it is green intentionally. Also known as sustainable chemistry, benign chemistry, or source reduction, green chemistry seeks to prevent the creation of hazards, instead of focusing on limiting the spread of pollutants or cleaning up waste. Its practices are encapsulated in twelve generally accepted guiding principles (Appendix I) that can be used by chemists to develop processes and assess how green a process is.

Examples of green chemistry include the development of pesticide alternatives that are effective at killing target organisms, but are benign to non-target organisms and do not persist in the environment. Another example is the use of the benign solvent supercritical carbon dioxide in dry cleaning processes instead of toxic perchloroethylene.

Pfizer and Shaw Industries provide good examples of the potential of green chemistry. Pfizer won a 2002 Presidential Green Chemistry Challenge Award for the redesign of the sertraline manufacture process. Sertraline is the active ingredient in Zoloft, which is used widely in the U.S. to treat depression. By applying green chemistry principles, Pfizer was able to eliminate 140 metric tons per year of titanium tetrachloride, 100 metric tons per year of sodium hydroxide, 150 metric tons per year of hydrochloric acid, and 440 metric tons per year of solid titanium oxide. These changes improve worker and environmental safety, reduce energy and water use, and double overall product yield. Shaw Industries won a 2003 Presidential Green Chemistry Challenge Award for the development of EcoWorx™ carpet tile. Historically, carpet tile backings have been manufactured using polyvinyl chloride (PVC). PVC is made from toxic feedstocks and its combustion results in toxic byproducts such as dioxin and hydrochloric acid. EcoWorx™ carpet tiles are made from low toxicity feedstocks and are recyclable.

What are the benefits of green chemistry?

Besides the inherent advantages to human health and the environment, green chemistry can offer economic advantages and improvements to worker safety, public safety, and national security.

Many in the private sector have recognized the potential savings that green chemistry offers. For example, by using benign chemical processes, businesses can avoid the costs associated with treating or cleaning up pollutants. Other savings can come from simply making more efficient use of raw materials (sometimes referred to as "atom economy") and energy. Dow Chemical Company's Midland, Michigan facility is an example of the level of savings a company can achieve. In 1996 Dow partnered with the Natural Resources Defense Council to conduct a thorough review of the facility's processes to identify ways to implement more recycling and substitute benign materials for hazardous ones. By April 1999, after a one-time investment of $3.1 million, the facility had reduced emissions of targeted substances by 43 percent and the amount of targeted wastes by 37 percent primarily through green chemistry innovations. The improvements are saving Dow $5.4 million per year, a 174 percent annual return on investment.[1] However, even though these benefits are clear, this process has not been repeated widely by industry and not even by Dow itself. There are many barriers to adoption of green chemistry that are discussed later. In this case, one barrier was that even though the return on investment was good, Dow had other investment opportunities that offered even greater returns.

Many other inherent advantages come from green chemistry in the areas of worker safety, public safety, and national security. For example, many chemical processes are conducted at extreme temperature and/or pressure, two conditions that present a potential hazard for workers. Also, many processes involve toxic substances. Green chemistry seeks to design processes that can be conducted at or near room temperature and pressure, and that use benign substances. Both of these steps can improve working conditions for employees, and reduce the costs of liability protections for employers.

Chemical factories also pose a potential threat to public safety because of the possibility of an accidental release of toxic materials into the surrounding communities. Green chemistry seeks to replace these toxic substances with benign ones, which would not pose a threat to the public if accidentally released. Reducing the number of toxic chemical plants and the transport of toxic chemicals also improves national security by reducing the number of potential terrorist targets.

What barriers exist to greater adoption of green chemistry?

Despite the numerous potential advantages of green chemistry for the chemical manufacturing industry, adoption of green chemistry technologies has been limited. Significant impediments exist that discourage businesses from pursuing such alternatives. These include:

- **A workforce unfamiliar with green chemistry—**The existing chemical manufacturing workforce is mainly composed of chemists and chemical engineers that have little or no training in green chemistry techniques. Even today, most graduate chemistry curricula give little attention to green chemistry. Without appropriate personnel trained in green chemistry, a company may not know, or be able, to search for and implement green chemistry alternatives to their chemical processes.
- **Lack of existing green chemistry alternatives—**Green chemistry alternatives have not yet been designed for most of the chemical processes in use today. Developing a green chemistry alternative might be prohibitively expensive and time consuming, especially for companies that do not have extensive R&D programs and when time to market is critical.
- **Lack of demonstrated green chemistry alternatives—**Even for the green chemistry alternatives that do exist, many of them have not been proven in an industrial setting. Few companies are willing to take the risk of being the first to implement a new and unproven technology.
- **Costs of up-front capital investment—**U.S. companies have invested heavily in existing infrastructure. Switching to green chemistry processes might require this infrastructure to be extensively retooled, which could make adopting green chemistry technologies initially very expensive. Even though the process may be economical when costs are computed over the full life cycle, many companies may be unwilling to pay the high up-front costs. This is one reason why there is more green chemistry adoption in manufacturing sectors that turn over their processes more frequently.
- **Lack of regulatory drivers—**Few governmental incentives exist for adoption of green chemistry. Most environmental regulations sanction polluters,

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[1] Amato, Ivan, *Fortune,* New York: July 24, 2000, Vol. 142, Issue 3, pg. 270U.

while few reward pollution prevention. The government could make adoption of green chemistry more attractive by extending the patent life of green products or accelerating the approval of products that pose minimal hazard.

- **Inertia—**Perhaps the most important impediment to adopting green chemistry technologies is inertia within industry. For a company that already complies with all existing environmental regulations, there is little impetus to seek out and implement alternative processes. Additionally, few companies offer incentives to employees that improve environmental performance. This lack of motivation often means that only those companies that have made environmental sustainability a priority use green chemistry processes.

H.R. 3970 is designed to overcome some of these impediments. The bill would support undergraduate and graduate education in green chemistry. This should help create a new generation of chemists and engineers who are familiar with green chemistry and its advantages, and can bring those skills to bear in the workplace.

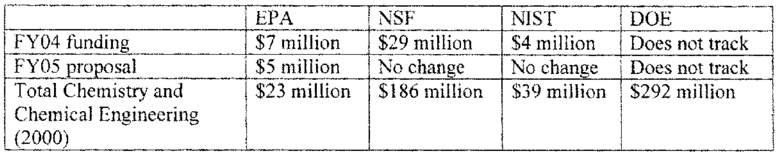
The coordinated R&D program would support R&D and demonstration projects at universities, industry and federal labs, and make the results of these activities readily available through a green chemistry database of accomplishments and best practices. This R&D would develop and demonstrate more green chemistry alternatives that will be available for implementation by industry.

What is the Federal Government currently doing?

The Federal Government supports activities related to green chemistry through agencies including NSF, EPA, DOE and NIST. In some cases, as with EPA, these activities are focused directly on green chemistry. In other cases, such as with DOE, these activities are byproducts of efforts to achieve other goals, such as improving energy efficiency. Because some green chemistry investments are direct and some are indirect, and because green chemistry is not broken out in agency budgets, it is difficult to determine the exact federal investment in green chemistry.

However, it is clear that the investment in green chemistry and chemical engineering is small as compared to the investment in chemistry and chemical engineering as a whole. In 2000, the four agencies mentioned above spent approximately $540 million on chemistry and chemical engineering R&D; investment in green chemistry R&D was probably close to $40 million. In addition, green chemistry activities are not coordinated among the agencies.

Following is a table that indicates, in general, agency budgets for green chemistry and chemical engineering activities. The table is followed by descriptions of how this money is spent.



	EPA	NSF	NIST	DOE
FY04 funding	$7 million	$29 million	$4 million	Does not track
FY05 proposal	$5 million	No change	No change	Does not track
Total Chemistry and Chemical Engineering (2000)	$23 million	$186 million	$39 million	$292 million

EPA conducts two general types of activities in green chemistry. EPA conducts and supports R&D through the Office of Research and Development; and EPA conducts outreach and promotion through the Office of Pollution Prevention and Toxic Substances (OPPTS).

In FY04, EPA will spend approximately $5 million on direct green chemistry and chemical engineering R&D. The money comes out of a larger spending category, called Pollution Prevention. Approximately half of this money is spent on internal R&D, conducted at EPA's lab in Cincinnati. The lab focuses on developing cross-cutting tools for industry such as benign solvent design software. The other half of this money funds external R&D, through the Science to Achieve Results (STAR) program. As part of this program, EPA and NSF have developed a partnership, the Technologies for a Sustainable Environment (TSE) program, which primarily funds green chemistry and chemical engineering R&D.

The TSE program is the external R&D program most focused on green chemistry in the Federal Government. The partnership between EPA and NSF has been hailed as a model of cooperation. EPA and NSF put out a joint request for proposals, and then award grants based on their own mission. NSF funds more basic green chemistry R&D, while EPA funds more applied R&D aimed at mission oriented problems.

TSE was initiated in 1995 and has awarded 204 grants totaling just over $56 million since then. In the FY05 budget, the Administration has proposed to cut EPA's funding for this program entirely.

EPA conducts outreach and promotes green chemistry (funded at approximately $2 million in FY04) through OPPTS. OPPTS administers the Presidential Green Chemistry Challenge Award Program. This award, first awarded in 1996 and given annually, recognizes achievements in green chemistry. Appendix II includes a number of examples of green chemistry achievements that have been recognized by this program. In FY05, the Administration proposes to increase funding for pollution prevention in OPPTS by $5 million. A portion of this funding will be used for green chemistry activities, including expanding the focus of the awards program to address existing and emerging chemical priorities.

Outside of the TSE collaboration with EPA, NSF does not put out specific solicitations for green chemistry R&D, but funds a wide range of investigator-driven green chemistry R&D. While NSF does not have a specific line item in the budget for green chemistry activities, NSF estimates that in FY04 it will spend approximately $10.8 million on green chemistry activities in the chemistry division and $13 million on green chemistry activities in the chemical transport systems division. However, it is difficult to determine the exact level of investment because much of this funding may be used for "multi purpose" fundamental research that has implications for green chemistry and other research areas. It is not the intent of the Green Chemistry Research and Development Act to decrease NSF's investment in green chemistry R&D; instead the bill seeks to focus more NSF funding specifically on R&D that is intended to advance green chemistry.

DOE does not track spending on green chemistry activities, and does not conduct activities that it specifically identifies as green chemistry. However, DOE conducts R&D that has many green chemistry applications. DOE's fundamental research efforts in chemistry are focused on attaining an atomic and molecular level understanding of processes involved in the generation, storage, and use of energy.

NIST has R&D programs that are yielding green chemistry results. NIST's mission is to develop and promote measurements, standards, and technology to enhance productivity and improve the quality of life. Much of the R&D conducted within this mission has green chemistry applications. For example, the Chemical Science and Technology Laboratory produces more accurate measurement methods and standards to enable the development and implementation of green technologies and assess its impact.

While the agencies above conduct a number of green chemistry-related R&D, these efforts are small when compared to their overall R&D, and even the chemistry and chemical engineering R&D budgets for these agencies. In addition, the efforts are not coordinated and are not strategic in nature.

6. Summary of H.R. 3970

The Green Chemistry Research and Development Act would authorize an interagency green chemistry R&D program. NSF and EPA would lead an Interagency Working Group to coordinate federal green chemistry activities. The Working Group would also include DOE and NIST, as well as any other agency the President designates. The program would be authorized at $26 million in FY05 rising to $30 million in FY07 (from within existing authorizations). See Appendix III for a break down of funding by agency.

The Program would support R&D grants, including grants for university-industry partnerships, support green chemistry R&D at federal labs, promote education through curricula development and fellowships, and collect and disseminate information about green chemistry. A complete section-by-section analysis of the legislation is provided in Appendix III.

7. Questions for the Witnesses

Questions for Dr. Bement

- Please describe the National Science Foundation's (NSF's) current activities in green chemistry. How much does NSF spend on green chemistry research? Through which NSF programs? How much emphasis is placed on basic research versus applied research and development?
- To what extent does NSF coordinate and collaborate with other federal agencies in green chemistry research and development?
- What are NSF's views on H.R. 3970, the *Green Chemistry Research and Development Act of 2004?* How could the bill be improved?

Questions for Dr. Gilman

- Please describe the Environmental Protection Agency's (EPA's) current activities in green chemistry. How much does EPA spend on green chemistry research? How much of this research is conducted intramurally versus extramurally? How much emphasis is placed on basic research versus applied research and development?
- To what extent does EPA coordinate and collaborate with other federal agencies in green chemistry research and development?
- What are EPA's views on H.R. 3970, the *Green Chemistry Research and Development Act of 2004?* How could the bill be improved?

Questions for Dr. Cue

- Please describe Pfizer, Inc.'s green chemistry activities. Have past investments in green chemistry paid off for Pfizer, Inc.? What environmental and human health benefits have resulted from Pfizer, Inc.'s green chemistry activities?
- What impediments exist that deter companies from pursuing green chemistry solutions? What more can the Federal Government do to encourage adoption of green chemistry products and processes?
- What are your views on H.R. 3970, the *Green Chemistry Research and Development Act of 2004?* How could the bill be improved?

Questions for Mr. Bradfield

- Please describe Shaw Industries, Inc.'s green chemistry activities. Have past investments in green chemistry paid off for Shaw Industries, Inc.? What environmental and human health benefits have resulted from Shaw Industries, Inc.'s green chemistry activities?
- What impediments exist that deter companies from pursuing green chemistry solutions? What more can the Federal Government do to encourage adoption of green chemistry products and processes?
- What are your views on H.R.3970, the *Green Chemistry Research and Development Act of 2004?* How could the bill be improved?

Questions for Dr. Woodhouse

- What is the potential of green chemistry products and processes to contribute to environmental protection and sustainability?
- What are some of the reasons that chemists have for so long relied on "brown chemistry"? What are the barriers to more rapid development and adoption of green chemistry alternatives?
- What should the Federal Government do to accelerate development and adoption of green chemistry products and processes?
- What are your views on H.R.3970, the *Green Chemistry Research and Development Act of 2004?* How could the bill be improved?

Appendix I

Twelve Principles of Green Chemistry[2]

1. It is better to prevent waste than to treat or clean up waste after it is formed.
2. Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product.
3. Wherever practicable, synthetic methodologies should be designed to use and generate substances that possess little or no toxicity to human health and the environment.
4. Chemical products should be designed to preserve efficacy of function while reducing toxicity.
5. The use of auxiliary substances (e.g., solvents, separation agents, etc.) should be made unnecessary wherever possible and innocuous when used.
6. Energy requirements should be recognized for their environmental and economic impacts and should be minimized. Synthetic methods should be conducted at ambient temperature and pressure.
7. A raw material of feedstock should be renewable rather than depleting wherever technically and economically practicable.
8. Unnecessary derivatization (blocking group, protection/deprotection, temporary modification of physical/chemical processes) should be avoided whenever possible.
9. Catalytic reagents (as selective as possible) are superior to stoichiometric reagents.
10. Chemical products should be designed so that at the end of their function they do not persist in the environment and break down into innocuous degradation products.
11. Analytical methodologies need to be further developed to allow for real-time, in-process monitoring and control prior to the formation of hazardous substances.
12. Substances and the form of a substance used in a chemical process should be chosen so as to minimize the potential for chemical accidents, including releases, explosions, and fires.

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[2] Anastas, P.T., Warner, J.C. *Green Chemistry: Theory and Practice;* Oxford University Press; New York, 1998, pg. 30.

Appendix II

Presidential Green Chemistry Challenge Award Winners

In 1995, the EPA initiated the Presidential Green Chemistry Challenge Award program to recognize achievement in green chemistry. Each year since 1996, awards have been given out in five categories: academic, small business, alternative synthetic pathways, alternative solvents/reaction conditions, and designing safer chemicals. Past winners have included:

- Pfizer, Inc. developed a green chemistry approach to the manufacture of setraline, the active ingredient in the anti-depressant Zoloft®. The new, streamlined process is accomplished in a single step instead of three, reduces consumption of some raw materials by as much as 60 percent, and uses a single, benign solvent instead of four. As a result, Pfizer, Inc. has improved worker and environmental safety, reduced energy and water use, and doubled overall product yield. *(Alternative Synthetic Pathways Award, 2002)*
- Shaw Industries, Inc. developed a novel type of carpet tile backing made from their EcoWorx™ compound. Traditional carpet tile backings are landfilled at the end of their useful life. Also, the combustion of PVC backings, the most commonly used carpet tile backings, produces toxic byproducts. EcoWorx™, on the other hand, is made from low toxicity feedstocks and is recyclable. The cost of collection, transportation, and recycling of EcoWorx™ carpet tile backings is less than the cost of using virgin raw materials. *(Designing Safer Chemicals, 2003)*
- SC Fluids, Inc. developed a new technology to improve manufacturing processes in the semiconductor industry. The fabrication of integrated circuits currently generates an estimated four million gallons of wastewater and uses thousands of gallons of corrosive chemicals and hazardous solvents per day. Supercritical CO_2 Resist Remover (SCORR) technology offers a cost-effective alternative by using supercritical CO_2 to strip resist from the silicon wafer. SCORR outperforms conventional resist removal techniques in the areas of waste minimization, water use, energy consumption, worker safety, feature size compatibility, material compatibility, and cost. *(Small Business Award, 2002)*
- Cargill Dow LLC developed a new family of polymers derived entirely from annually renewable resources that is competitive on a cost and performance basis with traditional plastics. Called NatureWorks™, it requires 20–50 percent less fossil resources than comparable petroleum-based plastics, and is fully biodegradable or recyclable. *(Alternative Solvents/Reaction Conditions Award, 2002)*
- Chemical Specialties, Inc developed an alternative wood preserving product called ACQ. More than 95 percent of pressure-treated wood is currently preserved with a chemical known as CCA. To manufacture CCA, approximately 40 million pounds of arsenic and 64 million pounds of hexavalent chromium (both probable carcinogens) are used. These chemicals may pose a risk to children through contact with CCA-treated items such as playground equipment. ACQ, however, does not contain arsenic or hexavalent chromium. Widespread adoption of ACQ has the potential to nearly eliminate the use of arsenic in the U.S., and would eliminate 64 million pounds of hexavelant chromium. This would also avoid the risks associated with the production, transportation, use and disposal of these chemicals. *(Designing Safer Chemicals Award, 2002)*
- Biofine, Inc. developed a novel technique to convert biomass waste into levulinic acid and its derivatives. Biofine, Inc., in collaboration with the Department of Energy, the New York State Energy Research and Development Authority, and Biometics, Inc., developed a method to convert biomass waste, including municipal solid waste, unrecyclable municipal waste paper, waste wood, and agricultural residues, into levulinic acid and its derivatives, which are marketable chemicals in many sectors. One full-scale commercial plant could convert 1000 dry tons of waste per day into 160 million pounds per year of product. *(Small Business Award, 1999)*
- Professor Joseph M. DeSimone from the University of North Carolina at Chapel Hill and North Carolina State University initiated a research program aimed at dramatically advancing the solubility performance characteristics of carbon dioxide (CO_2). More than 30 billion pounds of organic and halogenated

solvents are used each year that have a variety of negative impacts on the workplace and the environment. CO_2 has long been recognized as an ideal solvent, since it is nontoxic, nonflammable, safe to work with, energy efficient, cost-effective, waste minimizing, and reusable. This work has applications in the precision cleaning, medical device fabrication, garment care, and chemical manufacturing and coating industries. *(Academic Award, 1997)*

- BHC Company developed a new process for the manufacture of ibuprofen in which virtually all starting materials are either converted to product or are recovered and recycled. Using this process, the generation of waste is all but eliminated. This process has been hailed as a model of source reduction. *(Alternative Synthetic Pathways Award, 1997)*

Appendix III

Section-by-Section Analysis of H.R. 3970, Green Chemistry Research and Development Act of 2004

Sec. 1. Short Title

"Green Chemistry Research and Development Act of 2004"

Sec. 2. Definitions

Defines terms used in the text.

Sec. 3. Green Chemistry Research and Development Program

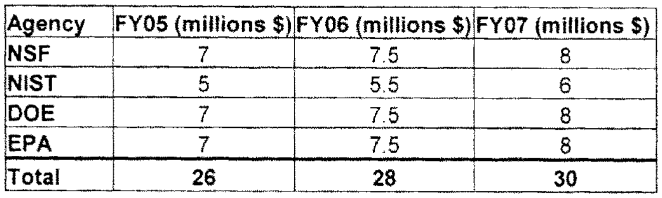
Establishes an interagency research and development (R&D) program to promote and coordinate federal green chemistry research, development, demonstration, education, and technology transfer activities. The program will provide sustained support for green chemistry R&D through merit-reviewed competitive grants to researchers, teams of researchers, and university-industry R&D partnerships, and through R&D conducted at federal laboratories.

The program will provide support for, and encouragement of, the application of green chemistry through encouragement of consideration of green chemistry in all federally-funded chemical science and engineering R&D; examination of methods to create incentives for the use of green chemistry; promotion of the education and training of undergraduate and graduate students in green chemistry; collection and dissemination of information on green chemistry R&D and technology transfer; and provision of venues for outreach and dissemination of green chemistry advances such as symposia, forums, conferences, and written materials.

Establishes an interagency working group composed of representatives from the National Science Foundation, the National Institute for Standards and Technology, the Department of Energy, the Environmental Protection Agency, and any other agency that the President may designate, to oversee the planning, management, and coordination of all federal green chemistry R&D activities. Names the Director of the National Science Foundation and the Assistant Administrator for R&D at the Environmental Protection Agency as co-chairs and requires the group to establish goals and priorities for the program and provide for interagency coordination, including budget coordination. Requires the group to submit a report to the Committee on Science of the House of Representatives and the Committee on Commerce, Science and Transportation of the Senate within two years that includes a summary of federally-funded green chemistry activities and an analysis of the progress made towards the goals and priorities established for the program, including recommendations for future program activities.

Sec. 4. Authorization of Appropriations

Authorizes appropriations for green chemistry R&D programs, from sums already authorized to be appropriated, at the National Science Foundation, the National Institute of Standards and Technology, the Department of Energy, and the Environmental Protection Agency.



Agency	FY05 (millions $)	FY06 (millions $)	FY07 (millions $)
NSF	7	7.5	8
NIST	5	5.5	6
DOE	7	7.5	8
EPA	7	7.5	8
Total	**26**	**28**	**30**

From sums already authorized to be appropriated for each of the agencies.

Chairman BOEHLERT. Good morning. I want to welcome everyone here today for our hearing on green chemistry, and I want to thank our colleague, Dr. Gingrey, for introducing the bill that will increase the focus of Congress, and, we hope, the Executive Branch, on this important and exciting area of research.

We scheduled our green chemistry hearing for today because it seemed like an especially appropriate topic for St. Patrick's Day, but it is really a timely subject, indeed a pressing subject, any day of the year.

While it is certainly true, to paraphrase the old adage, that without green chemistry, most of us—most of what we take for granted in modern life would be impossible. It is also true that chemicals compose a threat to life, and we are discovering more threats all of the time.

But many of those threats could be lessened and avoided entirely if we focused more of our research on green chemistry, on chemistry that reduces or eliminates the use of toxic substances and the generation of toxic byproducts. And the good news is that green chemistry solutions can also save companies money and give them a competitive edge, in addition to protecting the environment and workers. That all is very appropriate. Green chemistry can result in green cash as well as a green environment. It is the ultimate "win-win strategy." And I would direct your attention to our Director of Communications, who, appropriately, is dressed in green.

At least it is potentially. While the government and some companies have small and scattered efforts in green chemistry, it is rarely a central focus. That has to change.

And that will change only if the government takes action. The insufficient research in and application of green chemistry is a textbook example of market failure. Green chemistry has broad public benefits, but the market can not supply adequate incentives for the private sector to invest enough in it. The problems green chemistry solves are externalities, problems like pollution that have costs that are borne by the public at large rather than by their source. And inertia alone is enough to slow investment in new products and processes.

So Dr. Gingrey's bill takes a sensible and targeted approach. It says, "Let us focus more of the millions of the dollars the government already invests in chemistry research and development on green chemistry. And let us train more young scientists in this field. And let us make working on green chemistry R&D a conscious effort with an explicit budget." It is awfully hard to argue with that.

And indeed, we don't hear much argument. The bill has already been endorsed by the American Chemical Society, and industry is starting to line up behind it.

The Administration will tell us today that green chemistry is great, but we really don't need a bill. But that is what every Administration tells every Congress about just about every bill. I don't think we will be dissuaded by the traditional, "Don't worry; we have already got that covered," line of argument. Maybe green chemistry can develop a way to make Article I of the Constitution more indelible to Executive Branch readers.

So we look forward to reporting out this bill within the next month, and we hope for a time when the announcement of the Green Chemistry awards will be a red-letter day on everyone's calendar. Then we will really be able to achieve better living through chemistry. And I yield to—the balance of my time to the author of this legislation, Dr. Gingrey.

[The prepared statement of Chairman Boehlert follows:]

PREPARED STATEMENT OF CHAIRMAN SHERWOOD BOEHLERT

I want to welcome everyone here today for our hearing on green chemistry, and I want to thank our colleague, Dr. Gingrey, for introducing the bill that will increase the focus of the Congress—and, we hope, the Executive Branch—on this important and exciting area of research.

We scheduled our green chemistry hearing for today because it seemed like an especially appropriate topic for St. Patrick's Day, but it is really a timely subject—indeed a pressing subject—any day of the year.

While it is certainly true—to paraphrase the old ads—that, without chemistry, most of what we take for granted in modern life would be impossible; it's also true that chemicals can pose a threat to life—and we're discovering more threats all the time.

But many of those threats could be lessened or avoided entirely if we focused more of our research on green chemistry—on chemistry that reduces or eliminates the use of toxic substances and the generation of toxic byproducts. And the good news is that green chemistry solutions can also save companies money and give them a competitive edge in addition to protecting the environment and workers. Green chemistry can result in green cash as well as a green environment. It's the ultimate "win-win strategy."

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Mr. GINGREY. I thank the Chairman for yielding, and I want to first start off by thanking all, and certainly—and especially our panel of witnesses for being here today. I am looking forward to all—hearing your testimony. I wanted to also thank Chairman Boehlert and Ranking Member Gordon for holding this important hearing on green chemistry.

As a physician, I am a big believer in that old adage, "An ounce of prevention is worth a pound of cure." The majority of environmental protection laws passed by Congress focus on limiting the spread of pollutants, cleaning up waste, or assessing fines to polluters. We should be devoting more effort toward finding ways to prevent pollution in the first place rather than cleaning it up after it has been created. The *Green Chemistry Research and Development Act of 2004* does just that.

As a Chemistry major, trained in traditional chemistry, or what some have come to call "brown chemistry," I am very excited about the potential economic, environmental, and national security benefits from the emerging field of green chemistry. Preventing pollution and waste in the first place is often cheaper than mitigating and cleaning it up later, and the development of new products and processes will help spur economic growth. Green chemistry aims to design processes that can be conducted at or near room temperature and pressure and that use benign materials, decreasing the present risks for workers, while the replacement of toxic substances with safe ones reduces the potential threat to public safety due to accidental release. In our post-9/11 world, the reduction of the number of toxic chemical locations and the transport of toxic chemicals also improves national security by reducing the number of potential terrorist attacks and targets.

Yet despite all of the promise of green chemistry, the Federal Government invests very little, very little in this area. The Green Chemistry Research and Development Act establishes an interagency research and development program to promote and coordinate federal green chemistry research, development, demonstration, education, and technology transfer activities. I think that this bill provides modest and prudent funding in an area that deserves greater federal attention. I look forward to receiving the testimonies and engaging in dialogue on this very important area.

Mr. Chairman, I thank you, and I yield back the balance of my time.

[The prepared statement of Mr. Gingrey follows:]

PREPARED STATEMENT OF REPRESENTATIVE PHIL GINGREY

I thank the Chairman for yielding. I want to first start off by thanking all and our panel of witnesses for being here today, I'm looking forward to hearing your testimonies. I wanted to also thank Chairman Boehlert and Ranking Member Gordon for holding this important hearing on green chemistry.

As a physician, I'm a big believer in the old adage, 'an ounce of prevention is worth a pound of cure.' The majority of environmental protection laws passed by Congress focus on limiting the spread of pollutants, cleaning up waste, or assessing fines to polluters. We should be devoting more effort toward finding ways to prevent pollution in the first place rather than cleaning it up after it's been created. The *Green Chemistry Research and Development Act of 2004* does just that.

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Thank you Mr. Chairman and I yield back my time.

Chairman BOEHLERT. Thank you very much, Dr. Gingrey. And let me once again commend you for your leadership in this effort. That is the type of thing we have come to expect from the Members of this committee. We are at the forefront of so many things, and we are glad to be there once again.

The Chair is now pleased to recognize the distinguished Ranking Member of the Full Committee, Dr.—Mr. Gordon. I was going to give you a doctorate, too, Bart. You have had a few honoraries.

Mr. GORDON. Thank you, Mr. Chairman, and thanks for calling this important hearing. I concur with you that our goal here is to raise the awareness of the public and the Administration, and I think that this bill is a good start. Our champion on this side has been Ms. Johnson, who has taken a lead in this issue. And I would like to yield the balance of my time to her.

Chairman BOEHLERT. Before she takes the microphone, just let me commend Ms. Johnson, too, because it is her leadership, combined with Dr. Gingrey, working as a team, bipartisan, across the center aisle, that is making this happen. And I want to thank her for her leadership.

Ms. JOHNSON. Thank you very much, Mr. Chairman. And thank you, too, Ranking Member Gordon, for giving me this opportunity to speak on an issue that is so important to me.

Frequently, we, as legislators, preach about how we want to make this world a better place for those who are to follow. I, for one, want to help create a better planet, not only for the sake of my beloved grandchildren, but for all future generations.

Imagine a policy that can help clean the environment by increasing the use of renewable fuels, encourage manufacturing processes that generate less toxic waste and promote the development of materials which can be easily recycled. These are the goals of green chemistry. And this bill is an aggressive first step in reaching these goals. I am so pleased that my colleague, Congressman Gingrey, has introduced the *Green Chemistry Research and Development Act of 2004,* and I am proud to be an original cosponsor of this legislation.

Green chemistry is the utilization of a set of principles that reduces or eliminates the use or generation of hazardous substances in the design, manufacture, and application of chemical products. Green chemistry, as defined, tries to get at eliminating hazards in products and processes, making workplaces safer, dropping costs associated with safety and hazardous waste disposal, reducing risks to homeland security, preventing pollution, and creating healthier products that are effective and desirable. It is especially helpful in agriculture in conventional and organic crops. It has the capability of saving companies millions of dollars by reducing waste and providing a higher rate of return.

Over the past decade, there has been increasing interest in a fundamentally new approach to environmental protection. In studying green chemistry, we realize that science and technology can help produce processes and products that are both more environmentally benign and economically attractive.

An increased interest in new approaches for environmental protection may also derive, in part, from significantly changed attitudes about the environment over the past few decades. Increasing numbers of corporate executives may begin to see environmental protection as an important part of their corporate responsibility. Many firms now see an increased environmental consciousness as offering the potential for market niches that can emphasize the environmental benefits of products and services.

That is why I am so excited about our discussion of this legislation today. Although there is more work that can be done to strengthen this legislation, it still provides just the right impetus to encourage the science and manufacturing communities to start in the right direction, not only because green chemistry can save them money now, in the short term, but because it also can save our planet in the long term.

Thank you, Mr. Chairman, and I yield.

[The prepared statement of Ms. Johnson follows:]

PREPARED STATEMENT OF REPRESENTATIVE EDDIE BERNICE JOHNSON

Thank you, Mr. Chairman. And thank you too, Ranking Member Gordon, for giving me this opportunity to speak on an issue that is so important to me.

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[The prepared statement of Mr. Smith follows:]

PREPARED STATEMENT OF REPRESENTATIVE NICK SMITH

Today we meet to review the *Green Chemistry Research and Development Act of 2004.* The legislation establishes a modest interagency green chemistry R&D program at the National Science Foundation, Environmental Protection Agency, Department of Energy, and National Institute of Standards and Technology.

Green chemistry is defined as "the utilization of a set of principles that reduces or eliminates the use or generation of hazardous substances in the design, manufacture and application of chemical products." It is a relatively new term that describes relatively old ideas regarding our application of chemistry and related technologies to protect the environment. Today we actively think of such technologies as "green," and actively think "green" when applying these technologies.

By almost every indicator, the environment in the United States is substantially better than it has been at any time over the last thirty years. For example, emissions of chemicals such as nitrogen oxides from automobiles and mercury from power plants have decreased significantly. Drinking water is cleaner, and we're releasing much lower quantities of toxic chemicals into the environment in general. We have achieved all of this in concert with rapid population and economic growth.

How have we had such great success improving the environment? To be sure, sensible regulations and increased public awareness have been important overall contributors. But if I had to give an award to the single most important factor responsible for the clean environment in America today, it would be technology.

Technological advancement and information allows us to minimize wastes, improve efficiencies, and address nearly any environmental problem. So-called green chemistry is an important piece in this effort. As a farmer, I have to be tested and licensed to handle pesticides for the growing of crops. Thanks to our improved understanding and application of green chemistry, the safety of the chemicals I use on the farm has improved dramatically during the last 25 years.

Still, there is much room for improvement. We continue to have a problem with environmentally toxic chemicals in many industries. For example, in agriculture, we are searching for safer alternatives to potential environmental hazards such as Atrazine and Methyl Bromide. Green chemistry provides a fresh and different approach to addressing these ongoing environmental challenges.

Too often, we romance about the environmental benefits of regulations and other environmentally benign practices without regard to their impact on businesses and the economy. That approach is shortsighted, especially in today's globally competitive environment where even the most minor misguided regulation can drive entire industries overseas. With it's potential to provide non-regulatory, economically competitive solutions to some of today's most pressing environmental challenges, green chemistry can be a win-win approach to what is all too often a lose-lose situation.

To that end, the Federal Government can play an important role in stimulating green chemistry advances that are otherwise too risky and expensive for industry to undertake. The legislation before us today outlines that role and will hopefully move us closer to a broader goal I think we all share: economically friendly environmental protection through science, technology, and the dissemination of information.

I look forward to today's discussion.

[The prepared statement of Mr. Costello follows:]

PREPARED STATEMENT OF REPRESENTATIVE JERRY F. COSTELLO

Good morning. I want to thank the witnesses for appearing before our committee to examine federal and industry green chemistry research and development activities and to receive testimony on the *Green Chemistry Research and Development Act of 2004.*

Green chemistry is the use of chemistry for pollution prevention. More specifically, green chemistry is the design of chemical products and processes that reduce or eliminate the use and generation of hazardous substances.

Private industry has benefited from and contributed to green chemistry efforts. Pfizer and Shaw Industries should be commended for their work in this area. However, barriers to greater adoption of green chemistry products and processes by industry include a workforce unfamiliar with green chemistry, a lack of existing and demonstrated alternatives, the high capital costs of changing processes, and inertia.

I am interested to know about the current status of the Federal Government's efforts in green chemistry research and development and if efforts are underway to alleviate some of the above mentioned barriers. While agencies have conducted numerous green chemistry related R&D, these efforts are small, not coordinated and strategic in nature. Further, I am interested to know if expanded federal efforts and increased coordination in green chemistry is warranted and if so, how this legislation would further the effort.

I welcome our panel of witnesses and look forward to their testimony.

[The prepared statement of Ms. Jackson Lee follows:]

PREPARED STATEMENT OF REPRESENTATIVE SHEILA JACKSON LEE

Mr. Chairman,

Thank you for calling this timely hearing to discuss the importance of "green chemistry" and the federal investment in that important subject. I commend my colleague from Georgia, Dr. Gingrey, for authoring a bill that may help focus some of our attention on the need to encourage our schools, and labs, and industries to work toward protecting and preserving our environment.

I also welcome this distinguished panel. I thank you all for taking the time to be here today, to share your views on green chemistry and this bill.

I assume that everyone in this room is "for" green chemistry. It only makes sense that if there are two ways to do something—a harmful way and a non-harmful way—we would all want to choose the non-harmful way. And assuming we agree that it is a responsibility of the Federal Government to stimulate research and investment in areas that could have a beneficial impact on our nation, I believe we would all agree that we should focus some of the Nation's research energies on green chemistry.

The questions are: how much of our resources should be allocated to program, and where should they come from? These are especially tough questions in a budget environment like the one we have today. Massive tax cuts for the rich and a violent and expensive foreign policy have left us with little money left to fund critical programs.

The President's latest budget has slashed dozens of research and education programs. I have been very pleased with the bold leadership of the Chairman and Ranking Member of this Science Committee, pointing out that under-investing in science and technology is a grave error. It could jeopardize our position at the front of the world economy, and cost us jobs galore. I feel we need to find money to make investments in growth industries, and green chemistry certainly qualifies.

I am concerned, however, that the bill we are discussing, although well-intentioned, may not make the necessary improvement of investment in the field. Because the bill only draw from funds that have been previously authorized, existing programs will have to be cannibalized, or simply renamed to fit the "green chemistry" label. As important as green chemistry is, I would hate to see it come at the expense of programs at NIST or DOE that we have been fighting for years. Some of the programs that are to be incorporated into the green chemistry initiative have not even been re-authorized in years, further confusing the matter of funding.

Again, I am a firm supporter of green chemistry. It holds great promise for allowing our economy and standard of living to grow, while protecting our environment. However, I look forward to a serious discussion of how it will be funded, and what the bill we are discussing will accomplish.

Thank you.

Chairman BOEHLERT. Thank you very much.

Our witness list today, the sole panel we have, is Dr. Arden Bement, Acting Director, National Science Foundation, and a frequent visitor here.

Dr. BEMENT. Thank you, sir.

Chairman BOEHLERT. Dr. Paul Gilman, Assistant Administrator for Research and Development, Environmental Protection Agency. And let me commend Dr. Gilman and the Governor for the statement issued yesterday on mercury. Dr. Berkeley Cue, Vice President of Pharmaceutical Sciences, Pfizer Global Research and Development. Dr. Cue, good to have you here. Mr. Steven Bradfield, Vice President of Environmental Development, Shaw Industries, Incorporated. Mr. Bradfield. And Dr. Edward Woodhouse, Associate Professor of Political Science, Department of Science & Technology Studies at that great institution, Rensselaer Polytechnic Institute.

It is a pleasure to have all of you here. We would ask that you try to summarize your statement in approximately five minutes. The Chair will not be arbitrary, because we really want to hear what you have to say, but we also want the advantage of a dialogue between Members and the panel, and I would advise all that your statements will appear in the record in their entirety.

Dr. Bement.

STATEMENT OF DR. ARDEN L. BEMENT, JR., ACTING DIRECTOR, NATIONAL SCIENCE FOUNDATION

Dr. BEMENT. Thank you, Mr. Chairman. Good morning to you, to Ranking Member Gordon and Members of the Committee. I am pleased to have the opportunity to testify before you this morning on the National Science Foundation's support of research on green chemistry and engineering, and specifically on the legislation under consideration by the Committee.

Green chemistry and engineering are critical components of a comprehensive approach to manufacturing, an approach that considers not just the desired product, but the feedstocks, energy costs, purification procedures, and environmental impact associated with making the product.

Over the past dozen years, the National Science Foundation, principally through the Division of Chemical and Transport Systems and the Division of Chemistry, has been investing in basic research that supports this holistic view of what might be called "the molecular economy." Through existing partnerships with the Environmental Protection Agency, the Department of Energy, and the National Institute of Standards and Technology, NSF has been leveraging its investments in green chemistry and engineering for almost a decade.

In 1991, NSF announced a joint program in Environmentally Benign Chemical Synthesis and Processing, whose goal was to reduce the environmental footprint of manufacturing processes while maintaining economic competitiveness. In 1994, a Memorandum of Understanding was signed between NSF and EPA that had three components, one of which was a program to support Technology for a Sustainable Environment.

The current NSF investments in green chemistry and engineering are approximately $11 million per year in the Division of Chemistry, and $13 million per year in the Division of Chemical and Transport Systems. Areas of support include chemical synthesis, catalysis, separations research, and environmental research. Advances in chemical synthesis provide new products and alternative chemical routes to existing products that minimize or eliminate potentially harmful byproducts. New catalysts can be used to accelerate desired reactions, lower the energy costs associated with them, and reduce their hazards and environmental impact. Separations research can lead to more environmentally friendly and cost-effective methods for purifying chemical feedstocks and products.

NSF funding supports both individual investigators and multi-investigator interdisciplinary teams of researchers working on green chemistry and engineering projects. A number of young investigators supported through NSF's CAREER program have projects related to green chemistry and engineering. Adding value to NSF awards in these areas is a Memorandum of Understanding with NIST under which NSF awardees may apply for supplements that enable them to travel to NIST and take advantage of NIST facilities and expertise.

An example of a team approach to green chemistry and engineering is the Science and Technology Center for Environmentally Responsible Solvents and Processes, based at the University of North Carolina at Chapel Hill. The center has pioneered the industrial use of carbon dioxide as a reaction medium, thereby avoiding production, use, and subsequent release into the environment of contaminated water, volatile organic solvents, chlorofluorocarbons, and other noxious pollutants. DuPont has recently invested in the construction of a plant in North Carolina to use this technology in the manufacture of materials like Teflon. Research supported at this center has also yielded new, less hazardous dry cleaning technologies, and this research is being extended to process applications for the microelectronics industry.

Current manufacturing processes in the semiconductor industry involve toxic solvents, poisonous metals, and corrosive chemicals. The NSF Engineering Research Center on Environmentally Benign Semiconductor Processing, based at the University of Arizona with partners at Stanford University and MIT, is developing alternative technologies that both substitute safer materials in the production of semiconductor devices and minimize waste and water use. This Center has demonstrated the use of high-pressure carbon dioxide as a green solvent, and it has developed improved methods for water purification and recycling. In the past five years, this Center has spawned four new start-up companies that are commercializing their novel, environmentally friendly technologies.

Mr. Chairman, I would like now to briefly comment on the draft *Green Chemistry Research and Development Act of 2004.* As I mentioned earlier, NSF and the Environmental Protection Agency have an ongoing, sustainable environmental program that appears to be meeting many of the goals of this bill. NSF has worked with both the Department of Energy and NIST in this area, as well. So we are in complete agreement on the value of research and processes and products that reduce the generation or use of hazardous substances. And I might add that my visit last night with the bright, young people in the Intel Science Award Program introduced me to at least two or three that are very active in this field, and I was very heartened by that. Although we welcome congressional attention and oversight in this area, we are always concerned about the unintended consequences of codifying research programs into law. While we look forward to working with the Committee to implement the goals of this legislation, the Administration believes that it is unnecessary to enact this legislation at this time.

Thank you for this opportunity to testify on a topic of great importance to the science and engineering community, to the economy, and to the environment, and I would be pleased to respond to any questions that you might have.

[The prepared statement of Dr. Bement follows:]

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Beginning in 1991, the two NSF divisions announced a joint program in Environmentally Benign Chemical Synthesis and Processing, whose goal was to reduce the environmental footprint of manufacturing processes while maintaining economic competitiveness. In 1994, a Memorandum of Understanding (MOU) was signed between NSF and the EPA that had three components, one of which was a program to support Technology for a Sustainable Environment (TSE). The TSE program, launched in 1995 and administered nearly annually since then, will be formally reviewed in May, 2004. In addition, some components of Biocomplexity in the Environment, an NSF Priority Area, support studies of the use of resources and pollutant transport in the environment.

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NSF funding supports both individual investigators and multi-investigator, interdisciplinary teams of researchers working on green chemistry and engineering projects. Projects typically include undergraduate and graduate students and postdoctoral research associates, who are trained through these awards. A number of young investigators supported through NSF's CAREER program have projects related to green chemistry and engineering. Adding value to NSF awards in these areas is an MOU with NIST under which NSF awardees may apply for supplements that enable them to travel to NIST to take advantage of NIST facilities and expertise.

An example of a team approach to green chemistry and engineering is the Science and Technology Center for Environmentally Responsible Solvents and Processes, based at the University of North Carolina at Chapel Hill (Partners include North Carolina State University, North Carolina A&T University, the University of Texas at Austin, Georgia Institute of Technology, and a large number of industrial affiliates). Research at this center has already led to new green manufacturing processes. For example, the center has pioneered the industrial use of carbon dioxide as a reaction medium, thereby avoiding production, use and subsequent release into our environment of contaminated water, volatile organic solvents, chlorofluorocarbons and other noxious pollutants. DuPont has recently invested in the construction of a plant in North Carolina to use this technology in the manufacture of materials like Teflon®. Research supported at this center has also yielded new, less hazardous dry cleaning technologies and this research is being extended to process applications for the microelectronics industry.

For example, current manufacturing processes in the semiconductor industry involve toxic solvents, poisonous metals, and corrosive chemicals. The NSF Engineering Research Center (ERC) on Environmentally Benign Semiconductor Processing, based at the University of Arizona with partners at Stanford University and MIT, is developing alternative technologies that both substitute safer materials in production of semiconductor devices and minimize waste and water use. This Center has demonstrated the use of high-pressure carbon dioxide as a green solvent in microchip fabrication and has developed improved methods for water purification and recycling. One of the young faculty members at Arizona was recognized this year as one of *Scientific American*'s 50 most influential researchers. In the past five years this Center has spawned four new start-up companies that are commercializing their novel, environmentally friendly technologies.

The NSF supports smaller projects in green chemistry and engineering involving partnerships of academic institutions with industry and/or national laboratories through its Grant Opportunities for Academic Liaisons with Industry (GOALI) and its Environmental Molecular Science Institutes (EMSI) programs. The EMSI program is managed by the Division of Chemistry and includes the Geosciences Directorate at NSF and the Department of Energy as partners. Several EMSI projects provide a molecular-level perspective on industrial processes that allow an understanding of their environmental impact at the level of ecosystems.

A measure of the quality of investments made through NSF awards is that nearly all of the academic winners who have received the EPA's Presidential Green Challenge Award have been NSF-supported investigators. This award recognizes major contributions to green chemistry and engineering research that have significant societal impact.

Broader impacts of green chemistry and engineering are supported both through a variety of technical workshops and through education and outreach activities. Many Research Experiences for Undergraduates (REU) projects provide summer research opportunities for advanced undergraduates in basic research related to green chemistry and engineering. Instrumentation and curricular investments across NSF likewise contribute to education and the development of the future workforce that will be needed to develop and implement ideas to promote green chemistry and engineering.

Mr. Chairman, I would like to briefly comment on the draft *Green Chemistry Research and Development Act of 2004.* As I mentioned earlier, NSF and the Environmental Protection Agency have an ongoing technology for a sustainable environment program that appears to be meeting many of the goals of this bill. NSF has worked with both the Department of Energy and NIST in this area as well. So we are in complete agreement on the value of research on processes and products that reduce the generation or use of hazardous substances. Although we welcome Congressional attention and oversight in this area, we are always concerned about the unintended consequences of codifying research programs into law. While we look forward to working the Committee to implementing the goals of this legislation, the Administration believes that it is unnecessary to enact this legislation at this time.

Thank you for this opportunity to testify on a topic of great importance to the science and engineering community, to the economy, and to the environment. I would be pleased to respond to any questions you might have.

BIOGRAPHY FOR ARDEN L. BEMENT, JR.

Arden L. Bement, Jr., became Acting Director of the National Science Foundation on February 22, 2004.

He joins NSF from the National Institute of Standards and Technology, where he has been director since Dec. 7, 2001. As head of NIST, he oversees an agency with an annual budget of about $773 million and an onsite research and administrative staff of about 3,000, complemented by a NIST-sponsored network of 2,000 locally managed manufacturing and business specialists serving smaller manufacturers across the United States. Prior to his appointment as NIST director, Bement served as the David A. Ross Distinguished Professor of Nuclear Engineering and head of the School of Nuclear Engineering at Purdue University. He has held appointments at Purdue University in the schools of Nuclear Engineering, Materials Engineering, and Electrical and Computer Engineering, as well as a courtesy appointment in the Krannert School of Management. He was director of the Midwest Superconductivity Consortium and the Consortium for the Intelligent Management of the Electrical Power Grid.

Bement came to the position as NIST director having previously served as head of that agency's Visiting Committee on Advanced Technology, the agency's primary private-sector policy adviser; as head of the advisory committee for NIST's Advanced Technology Program; and on the Board of Overseers for the Malcolm Baldrige National Quality Award.

Along with his NIST advisory roles, Bement served as a member of the U.S. National Science Board from 1989 to 1995. The board guides NSF activities and also serves as a policy advisory body to the President and Congress. He also chaired the Commission for Engineering and Technical Studies and the National Materials Advisory Board of the National Research Council; was a member of the Space Station Utilization Advisory Subcommittee and the Commercialization and Technology Advisory Committee for NASA; and consulted for the Department of Energy's Argonne National Laboratory and the Idaho National Engineering and Environmental Laboratory.

Bement joined the Purdue faculty in 1992 after a 39-year career In industry, government, and academia. These positions included: vice president of technical resources and of science and technology for TRW Inc. (1980–1992); deputy under secretary of defense for research and engineering (1979–1980); director, Office of Materials Science, DARPA (1976–1979); professor of nuclear materials, MIT (1970–1976); manager, Fuels and Materials Department and the Metallurgy Research Department, Battelle Northwest Laboratories (1965–1970); and senior research associate, General Electric Co. (1954–1965).

He has been a director of Keithley Instruments Inc. and the Lord Corp. and was a member of the Science and Technology Advisory Committee for the Howmet Corp. (a division of ALCOA).

Bement holds an Engineer of Metallurgy degree from the Colorado School of Mines, a Master's degree in metallurgical engineering from the University of Idaho, a doctorate degree in metallurgical engineering from the University of Michigan, an honorary doctorate degree in engineering from Cleveland State University, and an honorary doctorate degree in science from Case Western Reserve University. He is a member of the U.S. National Academy of Engineering.

Chairman BOEHLERT. Thank you very much, Dr. Bement, but once again, the Chair will observe, this Administration, like all previous Administrations, usually finds the work of Congress unnecessary. The Administration feels that the source of all wisdom is vested in 1600 Pennsylvania Avenue and the environs, but we want to be active, working partners——

Dr. BEMENT. I am your canonical messenger.

Chairman BOEHLERT. And I was pleased to see you note the relationship with NIST, because the Chair understands that you have some familiarity with NIST.

Dr. BEMENT. Yes, I do have some familiarity, and if I had more time, I could go into a long list——

Chairman BOEHLERT. For the benefit of the audience that might not be aware, Dr. Bement is taking over the responsibility of NSF to fill a void created by the retirement of Dr. Rita Colwell. He is on leave from his job as Director of NIST, where he has performed with exceptional skill. So they give him another burden, taking on, at least on a temporary basis, NSF. But Dr. Bement, we really appreciate——

Dr. BEMENT. Well, I would welcome, for the record, to submit work that NIST is doing in this area as well.

[The information referred to appears in Appendix: Additional Material for the Record.]

Chairman BOEHLERT. Thank you very much.

Dr. Gilman.

STATEMENT OF DR. PAUL GILMAN, ASSISTANT ADMINISTRATOR FOR RESEARCH AND DEVELOPMENT, ENVIRONMENTAL PROTECTION AGENCY

Dr. GILMAN. We welcome the Committee's interest, and look forward to working with you on your legislation, as it proceeds through the Congress.

A critical part of EPA's mission is really embodied in the green chemistry and green engineering that you are addressing in this bill. We have historically addressed the issue. We hope to focus on it in the future. It is the kind of science that takes us beyond the limits of “command and control” approaches to keeping our environment clean and cleaning it up. Recently, our Administrator challenged the Agency to try and accelerate our pace in improving the environment using science and technology, market-based mechanisms, results-oriented work and collaborations in large networks.

I would like to tell you a little bit about a new framework we are implementing in the research side of the organization, and more broadly, within which green chemistry and green engineering is captured. We will be releasing next week some solicitations in the area of “Collaborative Science and Technology Network for Sustainability,” really a cornerstone of our approach for the future, working with states, local government, and industry to address high-priority challenges with rigorous science. We will be announcing two pilots that we are initiating with the Delaware River Basin Commission and the Canaan Valley Institute in West Virginia looking at ecological restoration and watershed practices for sustainability. We are also opening up today a portal in sustainability on the EPA website, which is trying to organize the dozens of programs throughout the EPA that embrace principles of sustainability, the scientific tools, and the programs aimed at that, including green chemistry and green engineering. And lastly, in an effort to encourage a focus on sustainability in our university systems, we have released what we call a P3 Award. The P3 standing for people, prosperity, and the planet, really an effort to solicit, through competitive grants, projects, and interdisciplinary teams trying to address solutions to environmental challenges. The National Academy of Engineering has agreed to serve as a judging organization for us in that regard, and we are very pleased with the early response to that effort.

Your Green Chemistry R&D Act really does build on a lot of successes that have already taken place in government. We are in the process of trying to really document the productivity of those grants that have already been done. Looking at the first 64 that we have been able to gather information on, those 64 first grants under the Technology for a Sustainable Environment (TSE) program that we have done in collaboration with the NSF, have resulted in 347 articles, 25 chapters in books, six patents, and one of the recipients received a Nobel Prize for Chemistry in 2001. You will hear a lot of examples of successes today. I would only note several teams of our grant recipients at Georgia Tech are working at making water a better solvent and using water-based coatings to replace more hazardous solvents. You have heard the story of the CO_2 work in North Carolina, the work of Professor Dorgan on polylactic acid to make bio-based materials a feedstock for the future, and Professor Wool at Delaware working on, again, bio-based products where today John Deere is using bio-based products in the manufacture of its tractors. And Professor Wool even has a patent on a bio-based silicon replacement for silicon chips that would utilize chicken feathers as part of the matrix of those chips. And while you may laugh at that sort of thing, I would only note that the chip operates at about two times the pace of silicon-based chips.

So there are wonderful examples out there. Some of those that I named are noteworthy not just because of their curiosities, but because industry is investing not tens, but hundreds of millions of dollars in the commercial use of those technologies.

Some programs that have also borne fruit are things like the Presidential Green Chemistry Challenge. Just the award winners of that since 1996 represent a reduction of 326 million pounds of hazardous substances, 390 million gallons of water saved, and 120 million pounds of CO_2 reduction.

Those are the kinds of results that we think this work will lead to, and not only noting the competitive nature of those products, I should also point out that, for those projects I mentioned, those were grants in the late '90s. The time from the lab bench to the commercial enterprise for these kinds of research projects is on the order of 10 years or less. And this is a committee that often hears that the basic research is 20 years or more away from practical application. So the fruits of this work are being seen as we speak.

Thank you for the opportunity to testify today.

[The prepared statement of Dr. Gilman follows:]

PREPARED STATEMENT OF PAUL GILMAN

Good morning, Mr. Chairman and Members of the Committee, I am honored to appear before you today to discuss the U.S. Environmental Protection Agency's green chemistry and engineering research and development activities, the subject of the draft *Green Chemistry Research and Development Act of 2004.* The U.S. Environmental Protection Agency (EPA) welcomes the interest of the Committee on green chemistry and engineering. The subject of this bill represents a critical part of EPA's focus on environmental and human health protection. EPA historically has and continues to address the goals in the proposed legislation. I will highlight today some of our ongoing efforts in green chemistry and engineering.

Every day decisions are made at local, state, and regional levels that affect our quality of life. To the extent possible, each of these decisions, from new building construction, highway development or ecosystem management, should be based on the best available scientific information and scientific tools available. Industry leaders are also making decisions on chemical, product, and process design that will have significant environmental and economic impacts. Sustainability draws on sound science to support these decisions to protect our natural systems, to provide a higher quality of life for people, and to further a competitive economy.

By building on traditional "command-and-control" regulations, EPA has been refocusing its efforts by conducting and funding research in areas such as green chemistry and engineering, global change, economics and decisions sciences, watershed management, industrial ecology, environmental justice, ecological forecasting, and emerging technologies. In the future, EPA will continue to focus on rigorous science as a better way to advance EPA's mission of protecting human health and the environment.

INTRODUCTION

Administrator Leavitt has outlined EPA's strategy to achieve its mission quickly and efficiently based on four key components: science and technology innovation, market mechanisms, results, and collaborative networks. Science and technology innovation provides new, cost-effective alternatives that better protect human health and the environment. Results ensure that our programs and processes achieve environmental and human health results. Collaborative networks serve to solve problems through partnerships and open dialogues among private and public stakeholders.

EPA's next step in achieving its mission is to apply this framework to specific environmental and human health challenges. Traditionally, environmental protection programs have focused on a particular medium or problem through command-and-control regulations. These programs have been very effective at reducing point source pollution and improving environmental quality over the past three decades. However, the environmental challenges we face today involve several media types and diffuse sources that are less amenable to command-and-control programs. EPA is looking for solutions that seek to address the various causes of environmental problems and understand the interrelationships between human behavior and the environment in specific areas.

A place-based approach is one example that supplements and complements the traditional environmental protection approach by focusing on the health of an ecosystem and the behavior of the humans who live within the boundaries of the ecosystem, instead of concentrating on a specific medium or particular problem. This strategy, therefore, moves beyond media-based or issue-based strategies to a holistic perspective that will lead to comprehensive, long-term, sustainable solutions.

FOCUS ON SCIENCE AND TECHNOLOGY THROUGH GREEN CHEMISTRY AND ENGINEERING

EPA is focusing on science and technology programs that incorporate the principles of green chemistry and engineering. The concept of green chemistry and engineering is a very real and specific component of our science and technology. The goals of green chemistry and engineering move us towards innovation and collaboration for the mutual benefit of human health and the environment while furthering economic competitiveness. Green chemistry and engineering are unique in that they focus on inherently benign alternatives for chemical products and processes that can address many challenges in a broad, multi-media framework. The advances of green chemistry and engineering have demonstrated results that provide cost-effective environmental and human health improvements. For these reasons, green chemistry and engineering represent the kind of science on which EPA is focusing to move to the next level of environmental and human health protection.

Before I discuss EPA's specific programs in green chemistry and engineering, I want to describe the broader context of EPA's focus. Three approaches are underway that cut across Administrator Leavitt's framework of science and technology innovation, results, and collaborative networks including: the "Collaborative Science and Technology Network for Sustainability," the Sustainability Portal, and the P3 Award: A National Student Design Competition for Sustainability.

Collaborative Science and Technology Network for Sustainability (CSTNS)

At the cornerstone of EPA's focus on sustainability is the "Collaborative Science and Technology Network for Sustainability" (CSTNS). Through CSTNS, EPA will be funding innovative, regional-scale projects that address the high-priority challenges. These projects will be a testing ground for developing and applying tools while drawing on scientific understanding of the consequences of decisions and actions. CSTNS will provide an opportunity for communities, states, the private sector, EPA, and other government agencies to explore new approaches to environmental protection that are systems-oriented, forward-looking, and preventative.

EPA is developing a number of pilot projects that illustrate the potential for this approach. One pilot project that is under development in EPA's Region 3 (Pennsylvania, West Virginia, Virginia, Delaware, Maryland, and the District of Columbia) is sustainable watershed management in the Delaware River Basin. This project will develop and implement strategies for sustainable water resource management in a watershed threatened by high population growth. EPA will work in cooperation with the United States Geological Survey; Delaware River Basin Commission (DRBC); the Commonwealth of Pennsylvania; local municipalities; the Brodhead Watershed Association and other stakeholders to evaluate the effects of growth and land use on groundwater, stream flows, and ecology in Pocono Creek. Tools will be developed to determine the appropriate ground water withdrawal limits considering environmental, economic, and social concerns. Those limits will be implemented by Monroe County, Pennsylvania to maintain the high quality of life in the watershed as future growth occurs. Research findings and results will be transferred to other parts of the Delaware River Basin as well as to other regions of the country. As evidenced by this project, CSTNS will transcend traditional regulatory approaches for air, water and land and rely on a more place-based perspective that takes a long-term view while measuring short-term outcomes.

A second project, in collaboration with the Canaan Valley Institute; local communities; State and local governments of the Mid-Atlantic Highlands area (portions of Maryland, Pennsylvania, Virginia, and West Virginia); West Virginia University; and other stakeholders, will develop and evaluate sustainable restoration technologies. Methods for stream restoration, which address the problems of sedimentation, riparian habitat loss and biological degradation will be included. In addition to the environmental benefits, it is expected that there will be increased potential for job creation as a result of restoration activities. Research findings and results will be transferred throughout the Mid-Atlantic Highlands area as well as to other regions of the country.

We envision that these projects, as well as those funded under the upcoming competitive solicitation for the next phase of CSTNS projects, will serve to integrate the many existing EPA programs, identify gaps and demonstrate how such practices can be applied in the real world.

Sustainability Portal

EPA has dozens of programs and activities that support elements of science and technology for sustainability. To provide better access to these programs and work to integrate them, EPA is developing a web portal *(www.epa.gov/sustainability).* This portal will provide easy access to EPA tools and programs that can help individuals, communities, and institutions achieve their sustainability goals. Links are provided to EPA programs and research for planning and practices, scientific and technical tools, measuring results and evaluating progress. The programs and research presented under "planning and practices" promote the integration of existing social, economic and environmental policies while anticipating new programs. Long-range, integrated planning and educating the next generation in sustainability practices are also included. The "scientific and technical tools" section highlights the development of underlying scientific and engineering knowledge needed to develop sustainability tools and techniques. "Measuring results and evaluating progress" focuses on providing a science-based foundation for monitoring and assessing trends in the environment and providing support for decision-making in businesses, communities, and across government. The website provides a "one-stop" portal to EPA's programs and research appropriate to advancing the goal of sustainability.

P3 Award: A National Student Design Competition for Sustainability

To encourage the integration of sustainability into higher education and training, EPA launched the P3 Award competition in November 2003. "P3" was chosen to highlight people, prosperity and the planet—the three pillars of sustainability. The P3 Award is a partnership between the public and private sectors to achieve the mutual goals of economic prosperity while protecting the natural systems of the planet and providing a higher quality of life for its people. The P3 Award program *(www.epa.gov/P3)* will provide up to 50 grants to interdisciplinary teams of college students to research, develop, and design sustainable solutions to environmental challenges in both the developed and the developing world. A panel convened by the National Academy of Engineering will select the P3 Award winners at an event on the National Mall. The winner(s) of the P3 Award will be eligible for additional funds from EPA to match contributions from the private sector for further development, implementation and placement in the marketplace. This will ensure that EPA is supporting the research and development of innovative, inherently benign, integrated scientific and technical solutions that will advance the goal of sustainability.

EPA'S ONGOING PROGRAMS SUPPORTING GREEN CHEMISTRY AND ENGINEERING

The framework for EPA's ongoing programs is also based on Administrator Leavitt's four components that the Agency is adopting to better and more quickly achieve its mission: science and technology innovation, market-based mechanisms, results, and collaborative networks. Focusing on research, development, and implementation in this Agency-wide framework is one mechanism that EPA will use to move to the next level of environmental and human health protection.

While the approaches previously discussed were developed to address all of the framework's components, current EPA activities can also be classified using this model. The following sections highlight EPA's activities in green chemistry and engineering, and more broadly, based on science and technology innovation, market mechanisms, results, and collaborative networks.

Science and Technology Innovation

Green chemistry and engineering are a critical part of EPA's current activities on science and technology. Research, development, and implementation of green chemistry and engineering are components of both the extramural Science to Achieve Results (STAR) grant program as well as intramural activities.

The *Green Chemistry Research and Development Act of 2004* will build upon the active and successful research and development traditionally supported and conducted by the EPA. Since the mid-1990's EPA has partnered with the National Science Foundation on a grants program called Technology for a Sustainable Environment (TSE) that focuses on green chemistry and engineering. In addition, EPA's intramural research program is centered on innovative scientific and technical advances in alternative energy sources, alternative reactor design, alternative solvent and catalyst strategies, and green metal finishing.

EPA has supported green chemistry and engineering research in both its intramural and extramural research programs. Including support for personnel, approximately $6.9 million is included in the FY04 budget for green chemistry and engineering activities. Of this amount, research is about $5.1 million, including about $1.9 of personnel costs. About $2.4 million of the extramural funding is for competitive grants through the TSE program. (Approximately 70 percent of the research under TSE—which was $3 million in FY04—is focused on green chemistry and engineering.) Due to a redirection of funds within EPA, funding for EPA's portion of the TSE program was not provided in the President's FY05 budget request. However, grants funded with prior year resources will continue.

EPA's Small Business Innovation Research (SBIR) program is another funding mechanism for innovative science and technology with economic and environmental benefits. EPA has also concentrated on the potential for innovative technologies to move us to the next level of environmental protection. Efforts include third-party environmental technology verification (ETV), an environmental technologies opportunity web portal (ETOP), and the creation of the Environmental Technology Council (ETC). These programs focus on researching and developing a knowledge base to support the development sustainable alternatives, through green chemistry and engineering, to enhance or replace current designs that present environmental and human health challenges.

Except for the SBIR and ETV, program, EPA's research is pre-competitive. The research under TSE is relatively more fundamental and the in-house research is somewhat more applied. However, in both cases, the priorities for the research are driven by EPA's goals and the research is in support of those goals.

Technology for a Sustainable Environment (TSE)

Since 1995, EPA and the National Science Foundation (NSF) have been partners in the Technology for a Sustainable Environment (TSE) program, a grants program designed to support research in pollution prevention. TSE *(http://www.epa.gov/greenchemistry/tse.html)* is an integral part of EPA's research program to support Agency program offices and regions and demonstrates leadership in addressing emerging environmental issues and advancing science and technology. TSE strongly encourages the collaboration of interdisciplinary academic researchers with industrial investigators who represent the eventual customers for the products of this research.

Together, EPA and NSF have funded over 200 TSE grants totaling approximately $56 million for applied and fundamental research in the physical sciences and engineering that will lead to the discovery, development, implementation and evaluation of innovative environmentally benign molecules, products and processes. Due to a redirection of funds within EPA, funding for EPA's portion of the TSE program was not provided in the President's FY05 budget request. However, grants funded with prior year resources will continue. TSE research focuses on ideas that advance the development and use of innovative science, technologies, and approaches directed at avoiding or minimizing the generation of pollutants at the source. As such, TSE focuses primarily on green chemistry and green engineering research.

Green Chemistry. The goal of the green chemistry research portion, similar to the *Green Chemistry Research and Development Act of 2004,* is to develop safer commercial substances and environmentally benign chemical syntheses to reduce risks posed by the manufacture, use and disposal of commercial chemicals. By preventing pollution at its source and designing inherently benign chemicals and processes, green chemistry has the potential to reduce environmental risks while providing more cost-effective products.

Green Engineering. The green engineering supported by TSE focuses on developing novel engineering approaches for preventing or reducing pollution from industrial manufacturing activities. The scope of green engineering includes equipment and technology modifications, reformulation or redesign of products, substitution of alternative materials, and in-process changes. Although these methods are often linked to the chemical, biochemical, and materials process industries, they can be utilized in many other industries, such as semiconductor manufacturing systems.

Quantifying Benefits. TSE also encourages research in physical sciences and engineering that will lead to the development of novel measurement and assessment techniques for green chemistry and engineering, and pollution prevention. Activities in this area include life cycle analysis, computational simulations, and process design algorithms as well as the development of appropriate measurement methods to quantify outcomes in terms of direct benefits to human health and the environment

Environmental Benefits. To better demonstrate these benefits, research proposals for a grant under TSE must include a section entitled "potential impacts." While the research supported by this program may be related to an individual reaction, unit operation or unit process, the investigators must address the environmental benefits or impacts of the research in the broader context of the industrial system of which it is a part. In this regard, the proposal must contain a discussion of expected potential environmental benefits or impacts in the broadest systems sense, which could include considerations of the efficient use of natural resources and energy and materials flows in manufacturing, product use, recycling, recovery or ultimate disposal. In this section, it is strongly recommended that the investigator address issues such as: the pollutant or class of pollutants the research proposes to prevent or minimize; the seriousness and importance of the environmental problem; and how the proposed technology or method is more economical and more environmentally benign than current technologies or methods.

Results. The goal of the TSE program is the discovery of innovative chemical alternatives with economic and environmental benefits through the design of inherently benign chemicals, materials, and energy for reduced risks, liabilities, accidents, and vulnerabilities. The first 64 of the 211 research grants funded under the TSE program produced 347 peer-reviewed journal articles, 25 book chapters, and six patents. In addition, one of the investigators funded under TSE was awarded the 2001 Nobel Prize in Chemistry.

Examples of research conducted through TSE (Appendix 1) highlight the potential for green chemistry and engineering research supported by the Federal Government to move from the laboratory to the marketplace. This research demonstrates mutual benefits to the economy and the environment in a wide array of industrial processes from alternative solvents to renewable and biodegradable materials to benign alternatives for oxidation.

All the TSE products that moved to commercialization had an important feature in common. These scientific and technical advances met or exceeded current cost and performance criteria, were competitive in the marketplace, and benefited human health and the environment. While it is extraordinary that there are TSE examples (Appendix 1) that have moved from the bench to commercialization in such a short timeframe (less than ten years), it demonstrates the potential for scientific and technical innovation in green chemistry and engineering to mutually achieve environmental and economic goals in the long-term. These innovations provide a basis for science and technology for sustainability by achieving the mutual goals of economic prosperity while protecting the natural systems of the planet and providing a higher quality of life for its people.

Green Chemistry Program

EPA's Green Chemistry Program *(www.epa.gov/greenchemistry),* in collaboration with EPA's Office of Pollution Prevention and Toxic Substances, is directed at preventing pollution by promoting the design of less toxic chemical substances and identifying alternative chemical pathways that involve less toxic reagents or solvents and generate fewer toxic products or co-products. As part of this program, EPA initiated the Green Chemistry Challenge that includes an award to recognize those in industry and academia that have met the objectives of Green Chemistry in an exemplary way. The Challenge also includes TSE as a research component to enhance support for innovative, inherently benign alternative chemical products and processes.

The Presidential Green Chemistry Challenge Awards Program *(http://www.epa.gov/greenchemistry/presgcc.html)* is an opportunity for individuals, groups, and organizations to compete for annual awards that recognize innovations in cleaner, cheaper, and smarter chemistry. The Awards Program provides national recognition of outstanding chemical technologies that incorporate the principles of green chemistry into chemical design, manufacture, and use, and that have been or can be utilized by industry in achieving their pollution prevention goals.

Award nominations are invited that describe the technical benefits of a green chemistry technology as well as its human health and environmental benefits. The Awards Program is open to all individuals, groups, and organizations, both nonprofit and for profit, including academia, government, and industry. The nominated green chemistry technology must have reached a significant milestone within the past five years in the United States; e.g., been researched, demonstrated, implemented, applied, patented, etc.

To date, the Award winning technologies alone are responsible for the following cumulative green chemistry benefits since 1996: eliminating 326,000,000 pounds of hazardous substances from commercial and industrial products and processes; saving 390,000,000 gallons of water; and preventing 120,000,000 pounds of carbon dioxide emissions.

EPA's Intramural Science and Technology for Sustainability Research

The mission of EPA's intramural sustainability research *(http://www.epa.gov/ORD/NRMRL/std/index.html)* is to advance the understanding, development, and application of technologies and methods of prevention, removal, and control of environmental risks to human health and ecology. This research can be categorized by key areas including: alternative energy sources, alternative reactor design, alternative solvent and catalyst strategies, and green metal finishing. As a result of this research, several significant scientific and technical advances in green chemistry and engineering have been developed and implemented. In addition, the researchers have developed software tools to enable inherently benign design and measure environmental and human health benefits of scientific and technological advances (Appendix 2).

Alternative Energy Sources. This research involves the use of new energy sources, such as microwaves and ultrasonic waves, as a means to enhance reaction conditions. The primary benefits of this approach include the reduction of reaction times from hours to minutes, a significant reduction of by-product or undesirable product formation, an overall increase in conversion of feedstocks, and the elimination of harmful solvents.

Alternative Reactor Design. This research focuses on the use of new reactor designs to increase reaction efficiency and decrease energy consumption. These designs include a corona ozone generating reactor, a titanium dioxide (TiO_2) ultraviolet (UV) reactor, and a spinning tube-in-tube reactor. The first two designs are considered advanced oxidation technologies that are best suited for use in oxidation-type reactions. They provide benefits such as increased conversion to desired products and minimal solvent or catalyst usage. The third reactor design is used for process intensification, a step that minimizes the time required to complete a given reaction. This in turn significantly reduces or completely eliminates by-product formation and increases overall conversion of the feedstock.

Alternative Solvents and Catalysts. This research uses novel solvents and catalysts to increase reaction efficiency while minimizing the use of more traditional and harmful solvents. Strategies include using supercritical CO_2 as a reaction medium; using room-temperature ionic liquids as a reaction media; using benign hydrogen peroxide (H_2O_2) to replace traditional catalysts (oxidants) such as magnesium permanganate (KMnO4) and chromium trioxide/sulfuric acid (CrO3/H2SO4); and using nonvolatile, alternative, polyethylene glycol (PEG) to replace traditional solvents.

Green Metal Finishing. EPA is working cooperatively with industry leaders in the metal finishing sector to provide green solutions to their most critical issues. The program has investigated the use of less toxic process alternatives for various metal finishing systems that are both energy efficient and cost effective, and in the end, more sustainable. The program has identified greener chemical replacements to several metal finishing processes, including hexavalent chromium. Presently, the program is evaluating green chemistry alternatives to chlorinated solvents and alkaline cleaners for degreasing operations in the metal finishing industry.

Additional Research. Additional intramural research focuses on industrial multimedia and systems analysis. The industrial multimedia research includes mine waste technology, metal finishing pollution prevention, metal forming, fuel cell applications, lead paint abatement, and base catalyzed dechlorination for contaminated soil remediation. The objective of the sustainable environments research is to construct a strategy for sustainable environmental management using economics approaches, water resource and land use planning, physical and ecological theory, and technological methods and knowledge implemented through computer-based tools, field data, and human experience to reduce risks to human health and the ecology. The main research efforts under systems analysis focus on life cycle assessments, cost engineering and cost benefit, chemical simulation and measurement, and pollution prevention at federal facilities.

Small Business Innovation Research (SBIR)

The EPA is one of 11 federal agencies that participate in the SBIR Program established by the *Small Business Innovation Development Act of 1982.* The SBIR program *(http://www.epa.gov/ncer/sbir)* supports research in cutting-edge environmental technologies. EPA issues annual requests for applications for Phase I and Phase II research proposals from science- and technology-based firms. Through this phased approach to SBIR funding, EPA can determine whether the research idea—often on high-risk advanced concepts—is technically feasible, whether the firm can conduct high-quality research, and whether sufficient progress has been made to justify a larger Phase II effort.

Historically, EPA has solicited projects on pollution prevention through SBIR. In 2004, however, EPA is focusing a significant portion of the program on pollution prevention and hazardous waste minimization. Working across EPA program and regional offices, we are soliciting highly relevant proposals to address pressing environmental challenges. These solicitations specifically request green chemistry and engineering innovations for alternatives to high-priority chemicals and environmental challenges ranging from inherently benign flame-retardants to lead and mercury alternatives to green building design. These newly solicited projects will become part of a legacy of pollution prevention science and technology successful developed under SBIR (Appendix 3).

Environmental Technology Verification

In October 1995, EPA established the Environmental Technology Verification (ETV) Program *(http://www.epa.gov/etv)*. The goal of ETV is to provide credible performance data for commercial-ready environmental technologies in order to speed their implementation for the benefit of vendors, purchasers, permitters, and the public. Because the level of potential environmental risk reduction for a technology is directly related to its level of performance and effectiveness, EPA verifies the performance of innovative, private-sector environmental technologies. It is important to note that private-sector technology developers produce almost all of the new technologies purchased in the United States and around the world. ETV offers purchasers and permitters of environmental technology an independent, objective, and high-quality source of performance information for informed decision-making.

Processes. EPA's ETV Program develops testing protocols and verifies the performance of innovative technologies that have the potential to improve how we protect human health and the environment. The ETV Program operates as a public/private partnership through agreements between EPA and private testing and evaluation organizations. These ETV verification organizations work with EPA technology experts to create efficient and fully quality-assured testing procedures that verify the performance of innovative technologies in air, water, soil, ecosystems, pollution prevention, waste, and monitoring. All quality assurance plans and protocols are developed with participation of technical experts, stakeholders, and vendors and are available prior to testing, peer reviewed by other experts, and updated after testing, as appropriate.

Results. Since ETV's inception in 1995, more than 200 environmental technologies have been verified and more than 70 protocols for technology testing have been developed. A 2001 survey of participating vendors indicated that 73 percent of the vendors were using ETV information in product marketing and 92 percent of those surveyed responded that they would recommend ETV to other vendors. To date, more than 25 vendors have returned to ETV for additional product verification.

Environmental Technology Opportunities Portal (ETOP)

The Environmental Technology Opportunities Portal (ETOP) *(www.epa.gov/etop)* is a web network designed to promote programs that foster the development of new, cost-effective environmental technologies and relay existing EPA environmental technology information (such as best available technologies for air, water and waste treatment and control).

ETOP highlights funding opportunities, information, and links to EPA and other programs that assist in development and commercialization and others that foster the use and acceptance of innovative technologies through collaborative recognition and incentive, and advocacy and information programs. Links are also provided to other agencies and groups outside EPA that offer environmental technology information.

ETOP was established as a result of a Congressional mandate through the FY 2003 House Appropriations Conference Report 108–10, page 1438. Congress directed EPA to develop a "one-stop-shop" office to coordinate similar programs that foster private and public sector development of new, cost-effective, environmental technologies. As part of the requirement to establish the "one-stop-shop" office, EPA established ETOP as an Internet portal page. ETOP was designed to clearly outline and highlight all of EPA programs as well as others that foster the development of environmental technologies, giving users direct access to funding and other incentive programs.

ETOP, while not specifically focused on science and technology for sustainability, provides a means to search on advances and opportunities at EPA in the areas of green chemistry and green engineering. ETOP provides a much needed mechanism to raise awareness and increase communication between the public and private sectors in developing and commercializing new technologies that benefit human health and the environment.

Environmental Technology Council (ETC)

EPA is presently establishing the Environmental Technology Council with members from all Agency technology programs, offices and regions. The ETC will enhance the communication and coordination of all EPA technology activities, especially for priority environmental problems. This will improve results of core regulatory, enforcement, and voluntary programs and will facilitate innovative technology solutions to environmental challenges, particularly challenges with multimedia or place-based elements. The challenges addressed will be clearly related to the Agency's strategic plans, advance the Agency's mission of protecting human health and the environment, and contribute to moving the Agency to sustainability—the next level of environmental protection.

Results

A focus on science and technology for sustainability will enable EPA and the Nation to more cost-effectively attain the ultimate environmental results of clean air, pure water, and protected land. Pollution prevention, achieved through the research, development, and market-adoption of green chemistry and engineering tools and technologies, is the foundation of such an approach. Green chemistry and engineering, along with environmentally benign manufacturing and industrial ecology, enable United States industries to design environmental benefits into their processes, products, and systems so that pollution and environmental hazards are avoided. These fields also enable United States industry to more effectively use benign materials and resources that are have the potential to benefit national security as well as the environment. Finally, these fields enable United States industry to remain economically competitive in the global marketplace by reducing risks, vulnerabilities, and the potential for accidents.

Future Plans. To better address outcomes and the recommendations of the Administration's Program Assessment Rating Tool (PART) analysis, EPA is making a strategic shift in its goals for Pollution Prevention and New Technologies (P2NT). The shift reflects the growing recognition that the goals of pollution prevention are the first steps in moving to the next level of environmental and human health protection. EPA is now focused on improving practices and approaches through P2NT. We are also developing a new research program, Science and Technology for Pollution Prevention and Sustainability (STPPS) that will be both intramural and extramural.

Intramural Program. Three overarching issues have been established to guide the direction and measure the progress of the new intramural STPPS program: identifying and defining sustainable systems; identifying metrics to measure progress towards sustainability; and developing methods, technologies, and approaches that can contribute to sustainability-based policies. This represents a shift to place-based environmental challenges that can be diffuse and have multi-media elements.

EPA's green chemistry and engineering research is currently focused on pollution prevention activities. These scientific and technical advances will now be quantified in terms of sustainability metrics and focused on the highest priority environmental challenges for the Agency and industry. For example, research will be conducted on designing tradable credits programs for storm-water runoff control and developing sustainability criteria for critical ecosystem restoration. By refocusing the modeling and simulation strength of P2NT to a long-term goal of computational environmental protection, research outcomes will create simulated "ecological-economic-social" systems. Environmental decision-support tools and methods will deliver results on applying, calibrating, and validating current life-cycle models and applying them to sustainable technologies, policies, products and processes. This will lead to an intramural research program that is not only working toward EPA's mission and sustainability, but to one that can be quantified in terms of clear benefits to economic, environmental, and social systems.

Extramural Research. EPA's extramural research program is also refocusing its efforts towards sustainability with quantifiable results in terms of the Agency's mission. Primary research will support research to use materials and energy more effectively while shifting to more inherently benign materials and energy sources. The most significant way to move to inherently benign material and energy flows is to advance green chemistry and engineering and to demonstrate these advancements in terms of economic and environmental improvements. It is important to recognize multiple benefits of an extramural STPPS research program. Such a program develops underlying scientific and engineering expertise; stimulates broader adoption of principles and practices in an academic community such as in chemical sciences and engineering; and helps to educate the next generation of scientists and engineers.

EPA recognizes the importance of demonstrating quantifiable, meaningful outcomes from our intramural and extramural research programs. The work to date has resulted in significant benefits to human health and the environment and future directions will build upon this legacy. By integrating these results into new research activities, EPA will be in a position to establish that economic and environmental goals can be achieved simultaneously and sustainably.

Collaborative Networks

EPA consistently uses collaborative networks to advance its mission of protecting human health and the environment. EPA's focus on science and technology sustainability also depends on working within EPA, across the government, and throughout the private sector to bring the most relevant science to all stakeholders to improve the economy and the environment for social benefit. These networks include EPA's program offices and regions, working through the National Science and Technology Council's Committee on Environment and Natural Resources (CENR), and collaborating with other Agencies including the Department of Energy (DOE), National Science Foundation (NSF), and the National Institute of Standards and Technology (NIST). EPA also reaches out to state, local, and tribal governments as well as the private sector and non-governmental organizations (NGOs) on issues of sustainability.

EPA's Program Offices and Regions

EPA's research and development activities are intimately related to activities in the program offices and regions. While these relationships exist throughout the Agency and across the Agency's mission, the following examples will focus on collaborations of EPA's Office of Research and Development with the EPA's Office of Solid Waste and Emergency Response and Office of Water as well as the regional offices that are advancing science and technology for sustainability.

Resource Conservation Challenge, Office of Solid Waste. The Resource Conservation Challenge (RCC) *(www.epa.gov/rcc)* is a major national effort to find flexible, yet more protective ways, to conserve our valuable resources through waste reduction and energy recovery activities. The RCC extends across EPA programs and media to include waste, water, air, toxics, pollution prevention, pesticides, and compliance, as well as activities in the regions, states, and tribes. The RCC identifies areas of program focus, or "challenges" that are ready for voluntary partnerships. Each of these challenges works to resolve national environmental problems by finding environmentally acceptable solutions that are long-term, preventative, comprehensive, and sustainable. One of the key areas of the RCC is "targeted chemicals." EPA has targeted 30 chemicals that are potential environmental hazards and challenged American industries to cutback on the use of these agents. As part of the RCC, EPA has pledged to support projects that help eliminate chemicals from the waste stream. The Agency's primary focus will be to secure commitments from the highest volume generators, sectors, and their related industry associations to reduce these chemicals in products, emissions, and waste. Clearly, green chemistry and engineering represents a vital area of research in meeting the RCC's targeted chemical challenge in a long-term, sustainable manner.

Smart Growth, Office of Water; Office of Policy, Economics, and Innovation; and Regional Offices. Smart growth *(http://www.epa.gov/livability/)* is development that serves the economy, the community, and the environment. It changes the terms of the development debate from the traditional growth/no growth question to "how and where should new development be accommodated." Smart growth answers these questions by simultaneously achieving healthy communities that provide families with a clean environment, balancing development and environmental protection, encouraging economic development and jobs, and promoting strong neighborhoods and transportation choices. Much research has been conducted to determine if a more balanced pattern of growth could benefit the environment. Preliminary results from these studies indicate that smart growth developments can minimize air and water pollution, facilitate brownfields cleanup and reuse, and preserve open space. Research must also be conducted to address how development patterns are influenced by market forces and by local, state, and federal policies and initiatives. Smart growth aims to minimize development's impact on the environment through sound site decisions and finding a sustainable balance of economic, social and environmental systems.

Interagency Collaboration

Critical to EPA advancing its mission and the goal of sustainability is close coordination and interaction with other government agencies. While EPA has many bilateral agreements with other agencies, such as the partnership with NSF for the TSE program and the Department of Energy through a formal Memorandum of Understanding, EPA also coordinates with other agencies through the Committee on Environment and Natural Resources (CENR) under the National Science and Technology

Council. The CENR addresses science policy matters and research efforts that cut across agency boundaries and provide a formal mechanism for interagency coordination relevant to domestic and international environmental and natural resources issues. The CENR recently discussed the addition of an Interagency Working Group on sustainability, clearly a crosscutting issue that EPA welcomes. The CENR has been an effective mechanism for working with other agencies and will serve as an excellent model for the new Interagency Working Group on Green Chemistry established under this bill. The CENR has played a role in significantly advancing collaboration with other agencies, specifically on issues related to sustainability, including advancing the mutual goals of economic growth and environmental protection.

State and Local Governments

Strong partnerships between EPA and the states achieve better environmental results. EPA has always worked with states to plan, set priorities, and encourage innovation to solve environmental problems. Most recently, EPA has begun to work with states to determine the most effective and appropriate ways for EPA to bring sound science to state-level decision-makers for environmental protection. At the same time, EPA is working with the Environmental Council of States (ECOS) to assess the sustainable development programs underway in the states and determine how states address their scientific needs in the context of meeting environmental goals. This project entails compiling a compendium of state sustainability activities, research needs, and existing means by which states access sound science. The compendium will include information about flagship sustainability projects in the states as well as an inventory of legislative, regulatory, and non-regulatory programs and tools. This represents one way in which EPA is working with states for improved environmental and human health protection as well as advancing the goal of sustainability.

Tribes

The American Indian Environmental Office (AIEO) coordinates the Agency-wide effort to strengthen public health and environmental protection in Indian Country, with a special emphasis on building tribal capacity to administer their own environmental programs. AIEO oversees development and implementation of the Agency's Indian Policy and strives to ensure that all EPA headquarters and regional offices implement their parts of the Agency's Indian Program in a manner consistent with Administration policy. One aspect of this relationship is the National EPA–Tribal Science Council, commonly referred to as the Tribal Science Council (TSC). The TSC was created in partnership with tribal representatives to help integrate Agency and tribal interests, specifically with respect to environmental science issues. The TSC provides a forum for tribes and EPA to identify priority environmental science issues and collaboratively design effective solutions to environmental concerns. Through this partnership, EPA and Indian Country are moving towards improved sustainable, comprehensive, long-term approaches to environmental and human health protection.

Beyond Government

EPA has extensive collaborations and partnerships beyond the government with non-governmental organizations (NGOs) and industry. Because these activities are so numerous, they cannot be included here. While many of the EPA's programs focused on sustainability—including the Collaborative Network for Sustainability and the P3 Award—encourage partnerships across a range of stakeholders, there are several existing examples that demonstrate collaborations specific to advancing science and technology for sustainability. The examples shown in Appendix 4 represent current ongoing activities in terms of green chemistry, green engineering, pollution prevention and sustainability with the American Chemical Society and other activities with the private sector through the National Environmental Performance Track.

CONCLUSION

By conducting research, developing green alternatives, implementing solutions, and measuring results, EPA will achieve its mission more quickly and more cost-effectively. Green chemistry and engineering are at the core of science and technology, and represent a critical component for EPA's move to the next level of environmental protection. Through science and technology innovations, demonstrated results, and collaborative networks, EPA continues to bring strong science to Federal, State, local, and tribal governments as well as the private sector for catalyzing action in protecting human health and safeguarding the environment. While we look forward to working with the Committee to meet the goals of this legislation, the Administration believes that it is unnecessary to enact this legislation at this time.

Appendix 1

Examples of Results from the EPA/NSF Technology for a Sustainable Environment (TSE) Grants Program

TSE Grant Example 1: In the first few years of the TSE program, research focused on environmentally benign solvents. Organic solvents are often toxic substances with widespread use as intermediates and final products. The early TSE research focused on identifying environmentally benign alternatives to toxic solvents such as liquid or supercritical CO_2, water, and ionic liquids. CO_2 became the primary focus of TSE research when EPA and NSF received numerous, high-quality proposals that addressed the key scientific questions related to the use of CO_2 as an alternative solvent. In 2003, EPA funded a "State of the Science" report on the use of CO_2 as a solvent that outlined the scientific progress and growing commercial interest in CO_2. The report noted that the "use of CO_2 as a solvent is fast becoming 'mature', an achievement due in large part to sustained funding in the area from EPA and NSF."

TSE-funded research has resulted in the development of CO_2-based processes as alternatives to organic or halogenated solvents for cleaning, treating, and coating surfaces. This work resulted from a 1997 grant awarded to Dr. Joseph DeSimone at the University of North Carolina-Chapel Hill. His research led to the development of specialty detergent systems that easily dissolve in CO_2. A small business was then created and funded by EPA under its Small Business Innovation Research (SBIR) program to advance this technology as an alternative to traditional dry cleaning. Implementing this technology in the dry-cleaning sector has resulted in significant reductions of perchloroethylene (perc) emissions (a suspected carcinogen) and the associated burdens of environmental regulations. This technology is now being used in five states and over 100 dry cleaning establishments.

These same technological advances used to develop CO_2 as an alternative solvent led Dr. DeSimone to develop a process to manufacture polytetrafluoroethylene (Teflon) using CO_2. This process replaced previous processes that used chlorinated chemicals or millions of gallons of water that needed to be treated before they entered the public water system.

DuPont, the manufacturer of Teflon, adopted this innovative process and announced that it would invest $275 million to build and operate a world-class manufacturing facility in Fayetteville, North Carolina, using this new technology.

The potential for CO_2 as an environmentally preferable solvent is now being realized in several additional areas, including separation processes in the food industry, coatings in the automotive and furniture industries, polymer production and processing, and cleaning processes for the garment care (dry cleaning) and microelectronics industries. The cost of ownership associated with the continued use of organic solvents is no longer a minor issue and CO_2 presents a unique, cost-effective, benign alternative to utilizing a potential environmental pollutant as a feedstock. For more information, see (http://cfpub.epa.gov/ncer_abstracts/index.cfm/fuseaction/display.abstractDetail/abstract/905/report/0).

TSE Grant Example 2: A critical component of waste minimization in fine chemicals manufacture is the substitution of classical organic syntheses using stoichiometric amounts of inorganic reagents with cleaner, catalytic alternatives. New and improved catalysts will enable important chemical reactions to be conducted under milder conditions, with less energy expenditure, in a shorter time, using less reactive and more environmentally friendly chemicals and solvents. For these reasons, catalysis is another area of research focus under TSE.

A TSE grant awarded by EPA in 1996 to Dr. Terrence Collins at Carnegie Mellon University, Pittsburgh, Pennsylvania, led to the development of oxidant activators based on iron. These activators promise extensive environmental benefits including a significant reduction in chlorinated pollutants. In addition, these alternative catalysts provide superior technical performance and significant cost and energy savings across a wide range of oxidation technologies.

Uses for these oxidant activators range from pulp and paper bleaching to fuel desulfurization to water disinfection, and most recently, biological or chemical decontamination for homeland security. In the case of pulp and paper bleaching, these activators proceed rapidly and efficiently at ambient temperatures with competitive performance while completely eliminating chlorinated pollutants.

More than 85 percent of recalcitrant sulfur compounds in refined automotive fuels can be easily removed using these powerful, environmentally friendly catalysts. Further development of this technology has the potential to provide an attractive alternative to existing methods that remove sulfur contaminants from fuels. Sulfur is associated with human health impacts, contributes to acid rain, and causes engines to burn less efficiently. This innovative technology demonstrates immediate environmental benefits by simultaneously reducing sulfur emissions from fuel combustion and improving fuel efficiency.

Given the widespread applicability of this technology and its demonstrated environmental and economic benefits, Dr. Collins is currently negotiating with several companies to manufacture these oxidants on a metric-ton scale for widespread use.

For more information, see (https://www.fastlane.nsf.gov/servlet/showaward?award=9612990).

TSE Grant Example 3: Another area of research concentration in the TSE program has been the use of renewable, bio-based feedstocks for chemical production. Use of renewable resources reduces the reliance on petroleum and has significant long-range strategic benefits for the U.S. Bio-based feedstocks also do not have environmental impacts associated with petroleum refining and processing. A “State of the Science” report on the development of this process and the contribution of TSE research is currently in progress.

A TSE grant awarded by EPA in 1998 to Dr. John Dorgan at Colorado School of Mines in Golden, Colorado, contributed to the development of the first family of polymers derived entirely from annually renewable resources that can compete with traditional fibers and plastic packaging materials on a cost and performance basis. These polymers are based on polylactic acid (PLA), a fully biodegradable and completely recyclable material, which is produced by fermenting and distilling corn sugar. PLA production also uses internal recycle streams to eliminate waste, resulting in over 95 percent yields and preventing pollution at the source.

This technology is the basis for the world’s first global-scale manufacturing facility capable of making commercial-grade plastic resins from annually renewable resources such as ordinary field corn. Cargill-Dow opened this facility in November 2001 after a $750 million investment. The plan now produces more than 300 million pounds of PLA annually and employs close to 100 people. From the corn plant to the retail counter, PLA has a lifecycle that reduces fossil fuel consumption by up to 50 percent. In addition, the process to make PLA generates 15 to 60 percent less greenhouse gases (GHG) than the material it replaces. Research also shows that technology advancements in PLA could allow up to 80 to 100 percent reduction in GHGs. This unique technology offers a new material alternative that competes on performance and price, while also reducing impact on the environment.

For more information, see (http://cfpub.epa.gov/ncer_abstracts/index.cfm/fuseaction/display.abstractDetail/abstract/967/report/0).

Appendix 2

Intramural Research, Development, and Implementation at EPA

As a result of EPA intramural research, several significant scientific and technical advances in green chemistry and engineering have been developed and implemented including:

- A novel process reactor, called a "Spinning Tube-in-Tube" or STT Reactor, has been used by EPA research staff to enhance the effectiveness of new catalysts. The STT Reactor, developed by Kreido Laboratories, consists of a small cylinder spinning within a hollow tube at speeds beyond 5500 rpm. This creates a well-stirred medium for chemical reactions such that mass transfer limitations can be either minimized or eliminated. The SST Reactor embodies the idea of process intensification through its potential for high throughput while maintaining a small physical footprint. Utilizing a CRADA with Kreido, EPA obtained an operating STT reactor for in-house experimentation. Employing the newly created EPA-designed catalysts, and using identical reaction conditions, researchers have been able to decrease the reaction time for partial selective oxidation of cyclohexane from four hours in a traditional batch reactor to below 25 minutes in the STT reactor. Currently, additional experiments with the STT Reactor are being negotiated under CRADAs to allow EPA researchers to develop other green chemistry applications for chemical production where significant toxic releases occur.
- Over the years, EPA's Green Metal Finishing program has evolved through close interactions with the regulatory programs in the offices of Water and Air Quality and Planning and Standards (OAQPS) in the Office of Air and Radiation. One project evaluated the use of fume suppressants for emissions control in hard chrome plating operations, an industry dominated by small businesses. Using this work, OAQPS revised their newly promulgated maximum achievable control technology (MACT) emission standards to include the results of the EPA demonstration of fume suppressants. The adoption of this technology resulted in multi-million dollar cost savings to industry, as well as major improvements in both EPA and Occupational Safety and Health Administration compliance. EPA was also involved with the metal finishing industry under the Common Sense Initiative (CSI) program involving industry, stakeholder groups, and the Agency's program offices including Office of Water, OAQPS and Office of Solid Waste. Ultimately, the CSI's Metal Finishing Committee developed a research agenda that was jointly implemented by EPA's laboratory and industry groups. EPA and the American Electroplaters and Surface Finishers Society jointly sponsor an annual conference to insure that the results of this research are transferred between the research office, program offices, and industry.
- Researchers in EPA developed a novel process reactor called a Corona Reactor. This reactor can be effectively and efficiently used in industrial oxidation processes, such as in the oxidation of alcohols and hydrocarbons for the production of value-added products. It can also be applied in advanced air and water cleaning processes. The Corona Reactor (patent pending) uses an oxidation protocol that has the advantage of the high oxidizing power of ozone formed within the reactor, as well as the photo-oxidation capability of UV light generated during ozone formation. This research has been conducted in collaboration with Washington University at St. Louis and a small business supported by EPA's SBIR program, Ceramatec, of Salt Lake City, Utah. The cleaning of indoor and airline cabin air are two potential applications of this. Other applications include the cleaning and partial and deep oxidation of waste gas streams from kraft pulp and paper mills. This ongoing study is being done in collaboration with Miami University and the Mead Westvaco Pulp and Paper Company of Chillicothe, Ohio.

As a result of EPA intramural research, several significant tools in science and technology for sustainability have been developed and implemented including:

- Program for Assisting the Replacement of Industrial Solvents (PARIS II): EPA is working to find cost-effective alternatives for industrial solvents that raise concerns for worker health and toxins in the environment. PARIS II is a software tool created to address this need by identifying pure chemicals or design mixtures that can serve as alternatives to more hazardous substances currently in use. The "greener" solvents formulated by PARIS II have improved environmental properties and can perform as well as the solvents they were designed to replace.

- Tool for the Reduction and Assessment of Chemicals and other environmental Impacts (TRACI): The most effective way to achieve long-term environmental results is to use a consistent set of metrics and a coherent decision-making framework. The EPA developed TRACI, a software package that characterizes the potential effects of specific chemicals or processes on ozone depletion and global warming, human health and the ecosystem. TRACI's modular design allows the most sophisticated impact assessment methodologies to be compiled. TRACI can be used in life cycle assessments, to improve design, set corporate environmental goals, plan a path to meet those goals, and then measure environmental progress.
- Waste Reduction Algorithm (WAR): In traditional chemical process design, attention is focused primarily on minimizing cost while the environmental impact of a process is often overlooked. This could, in many instances, lead to the production of large quantities of waste materials. It is possible to reduce the generation of these wastes and their environmental impact by modifying the design of the process. EPA recently developed a method to reduce wastes that is based on a potential environmental impact (PEI) balance for chemical processes. The PEI is a relative measure of the potential for a chemical to have an adverse affect on human health and the environment. The result of the PEI balance is an impact (pollution) index that provides a measure of the impact of the waste generated by a process. The goal of this methodology is to minimize the PEI for a process instead of minimizing the amount of waste (pollutants) generated by a process. The impact estimation algorithm is sophisticated and flexible enough to allow users to emphasize or de-emphasize different hazards as needed for particular applications. The result is a robust process design that integrally incorporates environmental impact reduction. The first version of the WAR Algorithm has been integrated into the commercial simulator ChemCAD IV under a Cooperative Research and Development Agreement (CRADA) between the EPA and Chemstations, Inc. A number of other CRADAs are being negotiated that involve further development of the WAR algorithm.

Appendix 3

Success Stories in Pollution Prevention from EPA's Small Business Innovation Research Program

SBIR Example 1: EnerTech Environmental, Atlanta, Georgia, has successfully developed an innovative process that chemically converts municipal sewage sludge, municipal solid waste, and other organic wastes into a high-energy, liquid fuel that is cleaner to combust than most fuels. This process eliminates the need to burn or bury organic wastes and begins to address the environmental burdens associated with combustion and landfills. Instead it produces E-fuel, a valuable and cleaner supplement or substitute for conventional fuels such as coal or oil.

For more information, see (http://cfpub.epa.gov/ncer_abstracts/index.cfm/fuseaction/display.abstractDetail/abstract/1517/report/0).

SBIR Example 2: Creare Incorporated, Hanover, New Hampshire, has designed a novel cutting tool-cooling system (CUTS) that eliminates the need for cutting fluids by indirectly cooling the cutting tool. Many companies use these costly and often environmentally problematic cutting fluids during machining operations. CUTS meets or exceeds current machining performance, including tool life and final product quality, when compared to traditional cooling systems that use cutting fluids. This technology uses a prevention-oriented approach that alleviates the human and environmental health and safety issues associated with cutting fluids.

For more information, see (http://cfpub.epa.gov/ncer_abstracts/index.cfm/fuseaction/display.abstractDetail/abstract/6098/report/0).

SBIR Example 3: Lynntech, Incorporated, College Station, Texas, is working to commercialize a fundamentally new, inorganic conversion coating that is chromium free and will protect aluminum from corrosion. Potentially toxic chromium conversion coatings are used extensively to protect aluminum parts for the aerospace, automobile, construction, and consumer products industries. Lynntech's newly developed protective coatings meet rigorous corrosion protection standards and also eliminate chromium exposure in the workplace and the environment.

For more information, see (http://cfpub.epa.gov/ncer_abstracts/index.cfm/fuseaction/display.abstractDetail/abstract/1375/report/0).

Appendix 4

Examples of Collaborative Networks with the Private Sector Related to Green Chemistry, Green Engineering, Pollution Prevention, and Sustainability

American Chemical Society (ACS): EPA and the ACS have partnered for the past eight years to host an annual Green Chemistry and Engineering Conference on issues that include global awareness, innovation, homeland security, and sustainability. A key objective of these conferences is to extend and strengthen the community of scientists, engineers, government officials, and the public in support of green chemistry. Conferences and symposia provide important opportunities for peer review, network building, increased awareness, and general development of a Green Chemistry community.

National Environmental Performance Track: This voluntary partnership program recognizes and rewards private and public facilities that demonstrate strong environmental performance beyond current requirements. The program is based on the premise that government should complement existing programs with new tools and strategies that not only protect people and the environment, but also capture opportunities for reducing costs and spurring technological innovation. Performance Track encourages participation of small, medium, and large facilities and its members are located throughout the United States and Puerto Rico.

All major industries are represented in Performance Track, with manufacturers of chemical, electronic and electrical, and medical equipment composing nearly 40 percent of the 344 members. Performance Track also provides recognition, regulatory flexibility, and other incentives that promote high levels of environmental performance and provide a learning network where best practices can be shared. The program encourages continuous environmental improvement through the use of environmental management systems. Public outreach, community involvement, and performance measurement are also important components of the program. Performance Track works within the business environment to encourage industry to reduce environmental emissions below regulated levels through approaches that are cost-effective.

For more information, see http://www.epa.gov/performancetrack.

BIOGRAPHY FOR PAUL GILMAN

In April 2002, Dr. Gilman was sworn-in to serve as the Assistant Administrator for the Office of Research and Development which is the scientific and technological arm of the Environmental Protection Agency. In May 2002, he was appointed the Agency Science Advisor. In this capacity, he will be responsible for working across the Agency to ensure that the highest quality science is better integrated into the Agency's programs, policies and decisions.

Before his confirmation, he was Director, Policy Planning for Celera Genomics in Rockville, Maryland. Celera Genomics, a bio information and drug discovery company, is known for having decoded the human genome. In his position Dr. Gilman was responsible for strategic planning for corporate development and communications.

Prior to joining Celera, Dr. Gilman was the Executive Director of the life sciences and agriculture divisions of the National Research Council of the National Academies of Sciences and Engineering. The National Research Council is the operating arm of the National Academies which were chartered to provide independent advice to the government in matters of science and engineering. Dr. Gilman's divisions focused on risks to health and the environment, protection and management of biotic resources, and practical applications of biology including biotechnology and agriculture.

Before joining the National Research Council. Gilman was the Associate Director of the Office of Management and Budget (OMB) for Natural Resources. Energy, and Science. There he coordinated budget formulation, regulatory, and legislative activities between agencies such as the Environmental Protection Agency, National Science Foundation, Agriculture, and Energy with the Executive Office of the President.

Dr. Gilman served as Executive Assistant to the Secretary of Energy for technical matters before joining the OMB. His responsibilities included participating in policy deliberations and tracking implementation of a variety of programs including the Department's environmental remediation and basic science research.

Gilman has 13 years of experience working on the staff of the United States Senate. He began that time as a Congressional Science Fellow sponsored by the American Association for the Advancement of Science in the office of Senator Pete V. Domenici. Later, as the Staff Director of the Subcommittee on Energy Research and Development, he was involved in the passage of the Nuclear Waste Policy Act of 1982 and oversight of energy technology and environmental research. Later he served as the chief-of-staff for Senator Domenici.

Dr. Gilman matriculated at Kenyon College in Ohio and received his A.B., M.A., and Ph.D. degrees in ecology and evolutionary biology from Johns Hopkins University, Baltimore, Maryland.

Chairman BOEHLERT. Thank you very much.

Dr. Cue.

STATEMENT OF DR. BERKELEY W. CUE, JR., VICE PRESIDENT OF PHARMACEUTICAL SCIENCES, PFIZER GLOBAL RESEARCH AND DEVELOPMENT

Dr. CUE. I need to have my first slide, please.

[Slide.]

Good morning, Chairman Boehlert and Members of the House Science Committee. Thank you for the invitation to be here today to describe Pfizer's green chemistry program. I will summarize the written testimony I have already submitted.

First, I will describe Pfizer's green chemistry activities and, in doing so, indicate how we believe these investments are paying off. I will also discuss what we believe are the environmental and human health benefits of pursuing green chemistry. I will address some important impediments to pursuing green chemistry solutions, and finally, I will share with you my views on the *Green Chemistry Research and Development Act of 2004.*

First, let me begin by telling you about Pfizer. Pfizer was founded in 1849 in Brooklyn, New York. Today, we are the world's leading health care company, with more than 130,000 employees worldwide and over $45 billion in annual sales. We have over 200 potential drugs in our R&D pipeline, and we spent over $7 billion in 2003 to discover, develop, register, and commercialize them.

[Slide.]

Pfizer is committed to a business model that is sustainable. Our environmental health and safety policy is based on the International Chamber of Commerce Charter on Sustainable Development. Sustainable development means meeting the economic, environmental, and social needs of the present without compromising the ability of future generations to meet their own needs.

[Slide.]

In 2002, Pfizer was the first U.S. pharmaceutical company to sign the U.N. Global Compact, committing us to nine principles on human rights, labor, and environmental performance.

[Slide.]

So what is green chemistry? I think several of you have already defined it the way I do. There are 12 principles that guide green chemistry, which is shown in this slide.

[Slide.]

Many chemists believe that the environmental gain usually comes at an economic cost. However, for every green chemistry principle, there is both an environmental and an economic benefit. Without a doubt, green chemistry has been a win-win proposition for Pfizer.

[Slide.]

Roger Sheldon, in 1994, reported that for every kilogram of drug produced in our industry, between 25 and 100 kilograms of waste are also produced. For those processes, we have redesigned—using green chemistry principles, we have been able to reduce this number to between five and ten kilos of waste, a five to ten-fold improvement. At typical commercial volumes, this equates to hundreds of thousands of kilograms of waste prevented each year for each product. This is a double economic benefit. We are not purchasing unnecessary raw materials or incurring the costs associated with treating and disposing this waste. Moreover, reducing the environmental profile of our processes removes potential health hazards from our environment.

[Slide.]

In 2002, Pfizer was awarded a U.S. EPA Presidential Green Chemistry Challenge Award for our improvements in the manufacturing process of sertraline with the following results: our manufacturing yield doubled, the benign solvent ethanol was now used for three of our conversions, almost 600 metric tons per year of solid waste and 250 metric tons per year of aqueous waste were eliminated. And as you can see in the lower left-hand corner of the slide, the number and volume of organic solvents were dramatically reduced.

[Slide.]

We achieved similar results for our manufacturing process improvements for sildenafil citrate, the active ingredient in Viagra, and received a Crystal Faraday Award in the United Kingdom last year.

Going forward, all Pfizer major drug product manufacturing processes are being evaluated for green chemistry improvements. Like any R&D activity, not all efforts will be successful, but when we are, the economic and environmental savings should be dramatic.

[Slide.]

Now let me address a couple of impediments. Today, there are very few students graduating with chemistry majors who are trained in, or even exposed to, green chemistry. So we are now educating our scientists about these principles. And to encourage this, teams with the best ideas are awarded an annual trophy, management recognition, and a cash prize to be donated to a college or a university of their choice to encourage green chemistry education.

[Slide.]

We are also reaching out to academic institutions near our R&D sites by hosting annual symposia where students are exposed to green chemistry with real-life case studies. They leave with a better understanding of how green chemistry is practiced in our industry.

One question that has repeatedly surfaced in green chemistry discussions is whether consumers will pay extra for environmentally benign products. The general consensus is they will not. As to the questions for this specific legislation, our experience teaches that an integrated approach to green chemistry at Pfizer that coordinates all of our efforts is a more effective way to a green chemistry strategy.

By analogy, this proposed legislation establishes a green chemistry R&D program to promote and coordinate federal green chemistry research, development, demonstration, education, technology transfer, and commercial application activities. These are all critical components of Pfizer's successful green chemistry program. The availability of merit-reviewed, competitive grants to support academic programs and promote education and training of undergraduate and graduate students in green chemistry should help to address the issue of lack of adequate green chemistry programs. And the charge of the Federal Government to create incentives for the use of green chemistry products and processes will help to address the issue of preferred treatment to—of companies who practice green chemistry.

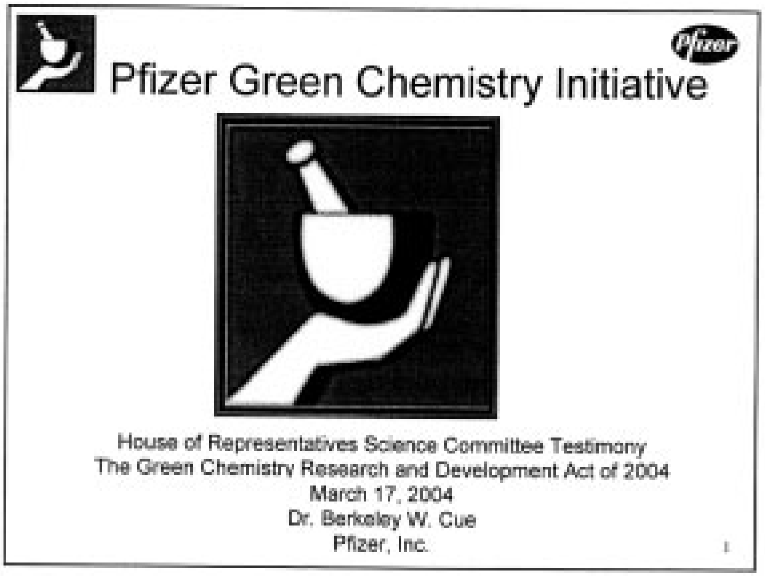
[Slide.]

In closing, I would like to thank the Committee for your attention. I believe green chemistry has the potential to produce the greatest change in the way synthetic chemistry is practiced in at least the last quarter century. It is already redefining how chemistry is thought about and practiced at every stage of R&D and commercial manufacture at Pfizer.

Thank you, again, for the opportunity to appear before this committee and to discuss Pfizer's green chemistry initiatives and the proposed legislation.

[The prepared statement of Dr. Cue follows:]

Prepared Statement of Berkeley W. Cue, Jr.



Pfizer Green Chemistry Initiative

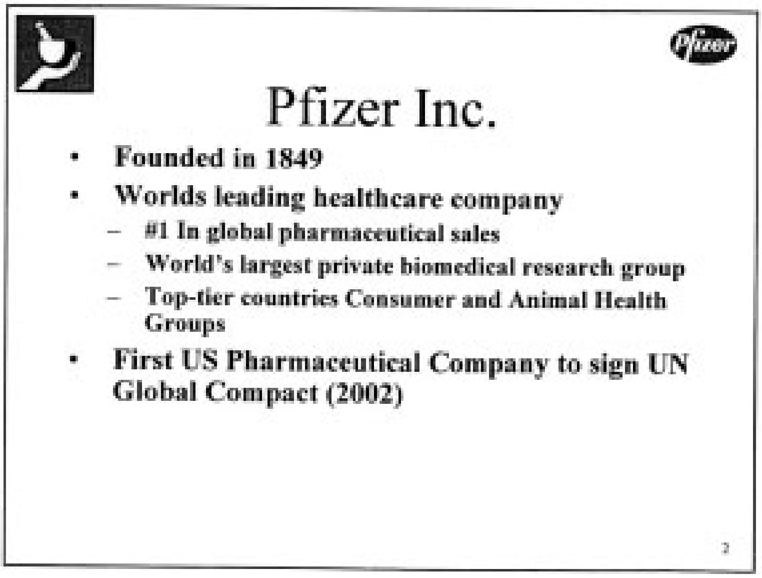
House of Representatives Science Committee Testimony
The Green Chemistry Research and Development Act of 2004
March 17, 2004
Dr. Berkeley W. Cue
Pfizer, Inc.

Good morning Chairman Boehlert and Members of the House Science Committee. I want to take this opportunity to thank you for the invitation to be here today to describe Pfizer's efforts around green chemistry and to help you understand why we believe green chemistry is a critical ingredient in our company's approach to corporate citizenship and in developing more efficient research processes.

Over the next few minutes I will do my best to address three topics. First, I will describe Pfizer's green chemistry activities and, in doing so, indicate how we believe these investments are paying off. Also, I will state as clearly as I can what we believe are the environmental and human health benefits of pursuing green chemistry.

I will address some important impediments to pursuing green chemistry solutions and provide some context to help the Members of this committee understand which areas could possibly benefit from more federal involvement in green chemistry.

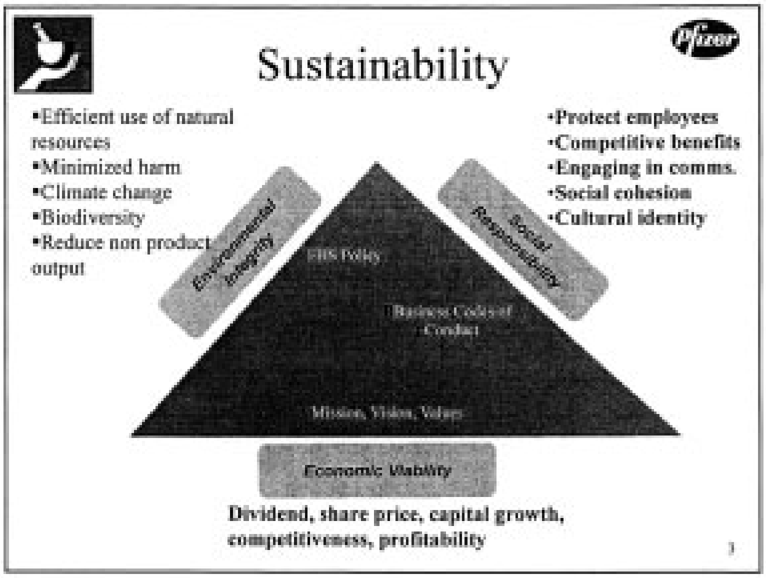
Finally, I will share with you my views on the *Green Chemistry Research and Development Act of 2004.*



Pfizer Inc.

- **Founded in 1849**
- **Worlds leading healthcare company**
  - **#1 In global pharmaceutical sales**
  - **World's largest private biomedical research group**
  - **Top-tier countries Consumer and Animal Health Groups**
- **First US Pharmaceutical Company to sign UN Global Compact (2002)**

First, let me begin by telling you about Pfizer. Pfizer was founded in 1849 in Brooklyn New York. The majority of the penicillin that went ashore with the Allied forces on D-day was made by Pfizer using a novel deep vat fermentation process. Today, we are the world's leading health care company, with more than 130,000 employees worldwide, over $45 billion in annual sales reported for 2003, more drugs rated number one in their therapeutic class in sales volume than any other company, we have over 200 potential products in our R&D pipeline and we spent over $7 Billion in 2003 to discover, develop, register, and commercialize these products. In addition to prescription human health care we have a large consumer health, or over-the-counter drug business and are ranked first in animal health care as well. I work in Pfizer Global R&D in the Groton, Connecticut Laboratories. There I lead the departments that are responsible for the design and optimization of the manufacturing processes for our active drug (API) and dosage forms such as tablets, capsules, and injectable formulations. I also lead the company's green chemistry efforts, working with colleagues around the world.



Sustainability

- Efficient use of natural resources
- Minimized harm
- Climate change
- Biodiversity
- Reduce non product output

- Protect employees
- Competitive benefits
- Engaging in comms.
- Social cohesion
- Cultural identity

Environmental Integrity

Social Responsibility

EHS Policy

Business Codes of Conduct

Mission, Vision, Values

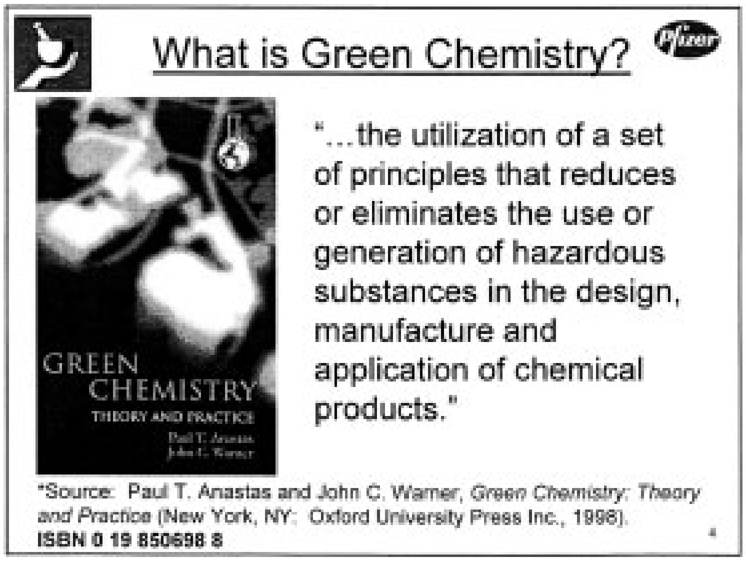
Economic Viability

Dividend, share price, capital growth, competitiveness, profitability

When a company achieves this sustained level of success we are expected to provide leadership. Pfizer is committed to a business model that is sustainable. Our environmental, health and safety or EH&S policy is based on the International Chamber of Commerce Charter on Sustainable Development. The Brundtland Commission's report in "Our Common Future" in 1987 states that sustainable development meets the economic, environmental and social needs of the present without compromising the ability of future generations to meet their own needs.

In 2002 Pfizer was the first pharmaceutical company to sign the U.N. Global Compact, committing us to nine principles on human rights, labor and environmental performance.

Our purpose statement is to dedicate ourselves to humanity's quest for healthier, happier lives through innovation and our mission is to become the world's most valued company to patients, customers, colleagues, investors, business partners and the communities where we live and work. Green Chemistry helps make all of this achievable.



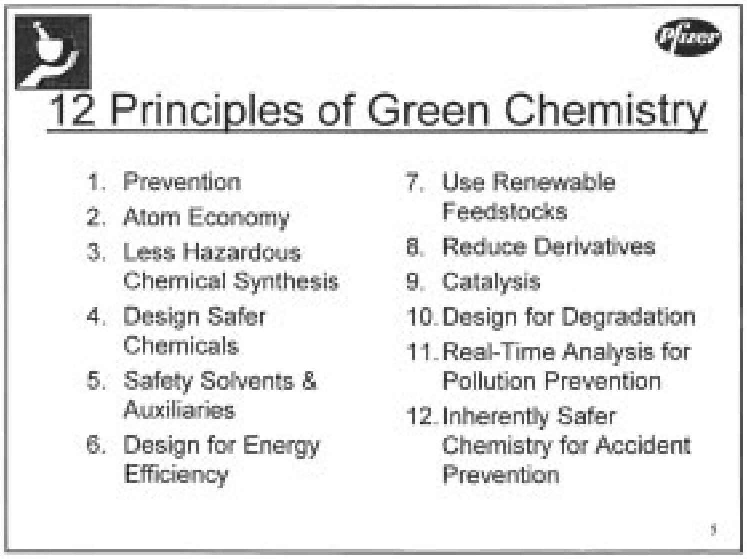
GREEN
CHEMISTRY
THEORY AND PRACTICE
Paul T. Anastas
John C. Warner

What is Green Chemistry?

"…the utilization of a set of principles that reduces or eliminates the use or generation of hazardous substances in the design, manufacture and application of chemical products."

*Source: Paul T. Anastas and John C. Warner, *Green Chemistry: Theory and Practice* (New York, NY: Oxford University Press Inc., 1998).
ISBN 0 19 850698 8

So what is Green Chemistry? The best articulation I've found is the one proposed by Paul Anastas from the White House Office of Science and Technology Policy (OSTP) and John Warner, Director of the Center for Green Chemistry at the University of Massachusetts-Boston and a Pfizer consultant for green chemistry. "Green Chemistry is the utilization of a set of principles that reduces or eliminates the use or generation of hazardous substances in the design, manufacture and application of chemical products."



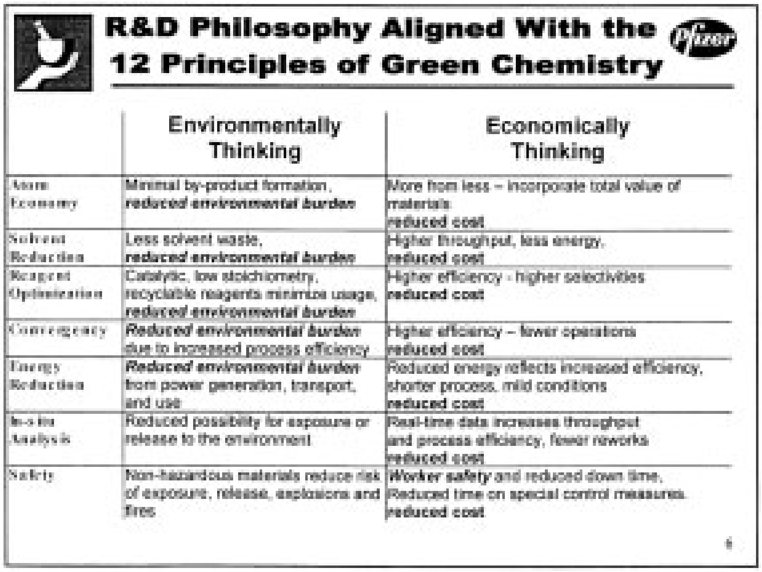
12 Principles of Green Chemistry

1. Prevention
2. Atom Economy
3. Less Hazardous Chemical Synthesis
4. Design Safer Chemicals
5. Safety Solvents & Auxiliaries
6. Design for Energy Efficiency
7. Use Renewable Feedstocks
8. Reduce Derivatives
9. Catalysis
10. Design for Degradation
11. Real-Time Analysis for Pollution Prevention
12. Inherently Safer Chemistry for Accident Prevention

The Twelve Principles of Green Chemistry

1. **Prevention:** It is better to prevent waste than to treat or clean up waste after it has formed.
2. **Atom economy:** Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product.
3. **Less Hazardous Chemical Synthesis:** Wherever practicable, synthetic methodologies should be designed to use and generate substances that possess little or no toxicity to human health and the environment.
4. **Design Safer Chemicals:** Chemical products should be designed to preserve efficacy of function while reducing toxicity.
5. **Safety Solvents and Auxiliaries:** The use of auxiliary substances (e.g., solvents, separation agents, etc.) should be made unnecessary wherever possible and, innocuous when used.
6. **Design for Energy Efficiency:** Energy requirements should be recognized for their environmental and economic impacts and should be minimized. Synthetic methods should be conducted at ambient temperature and pressure.
7. **Use Renewable Feedstocks:** A raw material of feedstock should be renewable rather than depleting wherever technically and economically practicable.
8. **Reduce Derivatives:** Unnecessary derivatization (blocking group, protection/deprotection, temporary modification of physical/chemical processes) should be avoided wherever possible.
9. **Catalysis:** Catalytic reagents (as selective as possible) are superior to stoichiometric reagents.
10. **Design for Degradation:** Chemical products should be designed so that at the end of their function they do not persist in the environment and break down into innocuous degradation products. For the Pharmaceutical Industry this principle is especially challenging since we are required to demonstrate our drug to be stable in the dosage form for the shelf life of the product.

11. **Real-Time Analysis for Pollution Prevention:** Analytical methodologies need to be further developed to allow for real-time, in-process monitoring and control prior to the formation of hazardous substances.
12. **Inherently Safer Chemistry for Accident Prevention:** Substances and the form of a substance used in a chemical process should be chosen so as to minimize the potential for chemical accidents, including releases, explosions, and fires.



R&D Philosophy Aligned With the 12 Principles of Green Chemistry

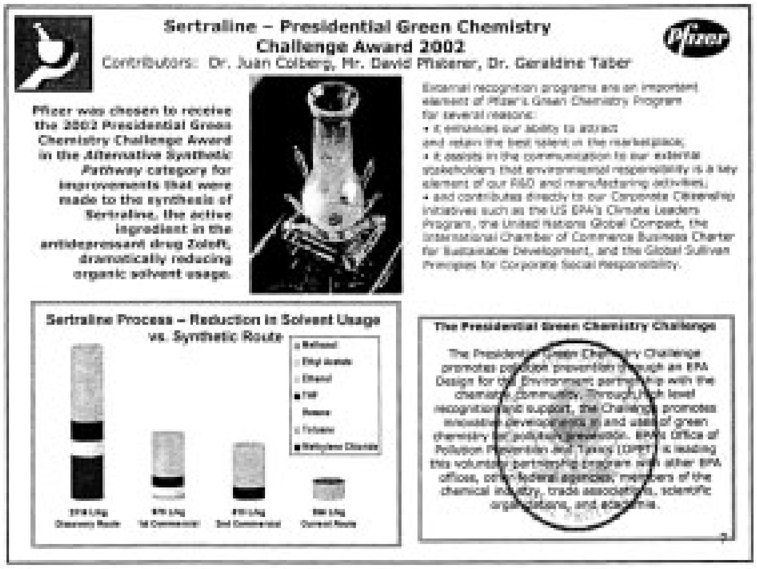
	Environmentally Thinking	Economically Thinking
Atom Economy	Minimal by-product formation, *reduced environmental burden*	More from less – incorporate total value of materials reduced cost
Solvent Reduction	Less solvent waste, *reduced environmental burden*	Higher throughput, less energy, reduced cost
Reagent Optimization	Catalytic, low stoichiometry, recyclable reagents minimize usage, *reduced environmental burden*	Higher efficiency - higher selectivities **reduced cost**
Convergency	*Reduced environmental burden* due to increased process efficiency	Higher efficiency – fewer operations reduced cost
Energy Reduction	*Reduced environmental burden* from power generation, transport, and use	Reduced energy reflects increased efficiency, shorter process, mild conditions reduced cost
In-situ Analysis	Reduced possibility for exposure or release to the environment	Real-time data increases throughput and process efficiency, fewer reworks reduced cost
Safety	Non-hazardous materials reduce risk of exposure, release, explosions and fires	*Worker safety* and reduced down time, Reduced time on special control measures reduced cost

Now I will address some of the benefits we have achieved by practicing green chemistry. The general perception among chemists who are not savvy about green chemistry is that the environmental gain usually comes at an economic cost. In this slide we demonstrate that for every principle there is both an environmental and an economic benefit. Thus, green chemistry supports our corporate citizenship to both environmental and economic performance. Without a doubt, it has been a win-win proposition for Pfizer.

Pfizer has been practicing the principles of process development and optimization for a long time. When we became aware of green chemistry in the late 1990's it seemed to us that this approach offered several benefits. We found a strong level of alignment between our traditional approach to chemical synthesis and process optimization with many of the principles, as well as a new way of thinking about chemical at all scales—from milligram quantities in the laboratory to tens of thousands of kilograms produced commercially.

An analysis of the performance of the pharmaceutical industry in terms of process efficiency published by Roger Sheldon in 1994 determined that for every kilogram of drug produces between 25 and 100 kilograms of waste are produced. For those processes where we have applied green chemistry principles we have been able to reduce this number to between 5–10 kilos of waste per kilo of product. *A 5- to 10-fold improvement!* At commercial product volumes this equates to hundreds of thousands of kilos of waste prevented each year for each product where we have succeeded in finding a greener chemistry alternative. There is a double economic benefit here-we are not purchasing raw materials that are lost to unwanted byproducts and we do not incur the expense costs associated with treating and disposing of this waste.

There may be some who believe zero waste is achievable. My view is that in preparation of complex organic molecules the production of by products is unavoidable. The goal of our chemists is to make this number as small as is technically feasible.



Sertraline – Presidential Green Chemistry Challenge Award 2002

Contributors: Dr. Juan Colberg, Mr. David Pfisterer, Dr. Geraldine Taber

Pfizer was chosen to receive the 2002 Presidential Green Chemistry Challenge Award in the *Alternative Synthetic Pathway* category for improvements that were made to the synthesis of Sertraline, the active ingredient in the antidepressant drug Zoloft, dramatically reducing organic solvent usage.

External recognition programs are an important element of Pfizer's Green Chemistry Program for several reasons:
- it enhances our ability to attract and retain the best talent in the marketplace;
- it assists in the communication to our external stakeholders that environmental responsibility is a key element of our R&D and manufacturing activities;
- and contributes directly to our Corporate Citizenship initiatives such as the US EPA's Climate Leaders Program, the United Nations Global Compact, the International Chamber of Commerce Business Charter for Sustainable Development, and the Global Sullivan Principles for Corporate Social Responsibility.

Sertraline Process – Reduction in Solvent Usage vs. Synthetic Route

The Presidential Green Chemistry Challenge

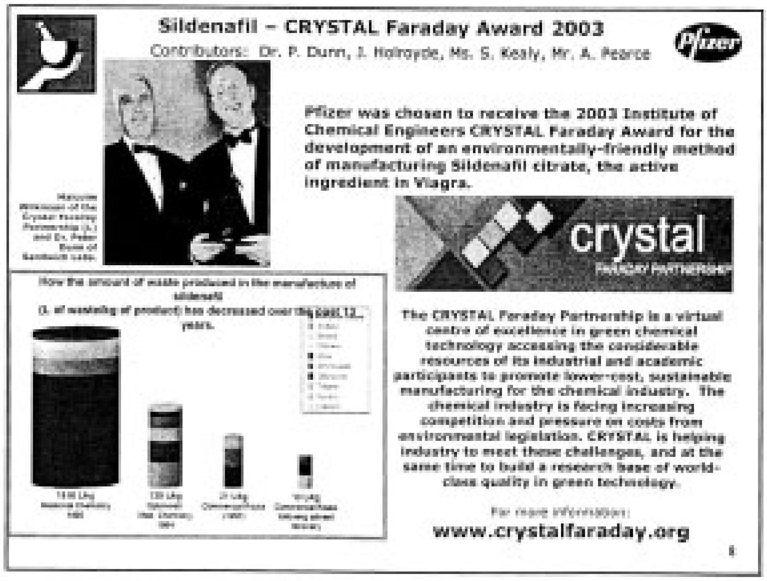
The Presidential Green Chemistry Challenge promotes pollution prevention through an EPA Design for the Environment partnership with the chemical community. Through high level recognition and support, the Challenge promotes innovative developments in and uses of green chemistry for pollution prevention. EPA's Office of Pollution Prevention and Toxics (OPPT) is leading this voluntary partnership program with other EPA offices, other federal agencies, members of the chemical industry, trade associations, scientific organizations, and academia.

In 2002 Pfizer was awarded a U.S. EPA Presidential Green Chemistry Challenge Award for our improvements in the manufacturing process of sertraline hydrochloride, the active ingredient in our anti depression product Zoloft. Please note in the lower left corner of the slide, the substantial reduction in overall solvent usage as well as the complete elimination of the use of methylene chloride, a highly hazardous substance.

Green Chemistry objectives were emphasized in the redesign of the sertraline process, resulting in quality chemical transformations with dramatic environmental and worker safety improvements. Manufacturing yield has essentially doubled. The benign solvent ethanol, obtainable from biomass, is now used for three synthetic conversions. The hazardous dehydrating reagent titanium tetrachloride was eliminated. A more selective catalyst now drives more complete conversion of the starting materials to racemic sertraline. *In-situ* resolution of the diastereomeric salts, through highly selective crystallization, is now used to produce pure S,S-sertraline. Overall, two intermediate isolations and a salt conversion step were eliminated.

The environmental and safety improvements are dramatic. Use of approximately 140 metric tons/year of titanium tetrachloride and the generation of 440 metric tons/year of problematic solid titanium dioxide wastes were eliminated. Approximately 150 metric tons/year of 35 percent HCl were eliminated. Neutralization of the highly acidic step 2, requiring approximately 100 metric tons/year of 50 percent NaOH, was eliminated. Consequently, high-salt waste streams are no longer produced. Dehydration additives and aqueous washes were eliminated, and the number and volume of solvents used were dramatically reduced. The efficiency of raw material, water, and energy use were dramatically improved.

The EPA is to be commended for sponsoring this award, not because we received it in 2002, but because it is contributing to raising the visibility of green chemistry and contributing to a cleaner, safer environment.



Sildenafil – CRYSTAL Faraday Award 2003

Contributors: Dr. P. Dunn, J. Holroyde, Ms. S. Kealy, Mr. A. Pearce

Pfizer was chosen to receive the 2003 Institute of Chemical Engineers CRYSTAL Faraday Award for the development of an environmentally-friendly method of manufacturing Sildenafil citrate, the active ingredient in Viagra.

How the amount of waste produced in the manufacture of sildenafil (L of wastes/kg of product) has decreased over the past 12 years.

The CRYSTAL Faraday Partnership is a virtual centre of excellence in green chemical technology accessing the considerable resources of its industrial and academic participants to promote lower-cost, sustainable manufacturing for the chemical industry. The chemical industry is facing increasing competition and pressure on costs from environmental legislation. CRYSTAL is helping industry to meet these challenges, and at the same time to build a research base of world-class quality in green technology.

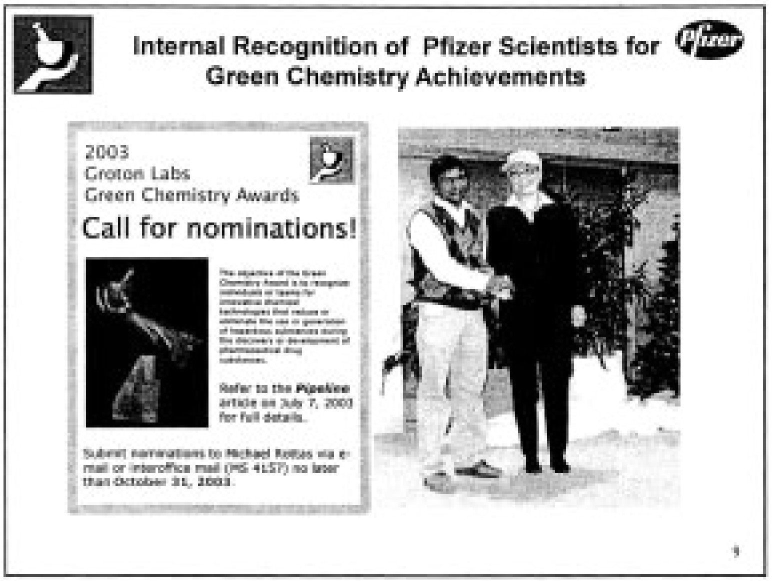
For more information:

www.crystalfaraday.org

This slide demonstrates that, following green chemistry principles, similar dramatic improvements have been achieved for the manufacture of sildenafil citrate, the active ingredient in Viagra, our drug for treating erectile dysfunction. This improvement was recognized with a 2003 Crystal Faraday Award, presented by the Institute of Chemical Engineering in the United Kingdom. The efficiency factor for this process is below 10, down from a typical 25 or greater for pharmaceutical manufacturing processes developed in the absence of green chemistry considerations.

This year we have submitted three applications for U.S. EPA Presidential Green Chemistry Challenge Awards for improvements in the manufacturing processes to celecoxib, the active ingredient in our anti arthritis agent Celebrex, for quinapril hydrochloride, the API in Accupril for treating high blood pressure and for sildenafil citrate, which I already described. Going forward all, major drug product manufacturing processes are being evaluated for green chemistry improvement potential. Like any R&D activity, not all efforts will be successful, but when we are the economic and environmental savings can be dramatic.

There are other benefits as well. Our leadership in green chemistry has improved our ability to attract and retain the best synthetic chemists in the marketplace. Today's graduating students are more environmentally conscious. They asked tough questions and we have good answers. Our green chemistry program allows us to communicate with external stakeholders about our commitment to corporate citizenship and sustainability. Last year we maintained our position in the pharmaceutical sector Dow Jones Sustainability Index, which enhances our shareholder value, in part because of our leadership in green chemistry.



Internal Recognition of Pfizer Scientists for Green Chemistry Achievements

2003
Groton Labs
Green Chemistry Awards

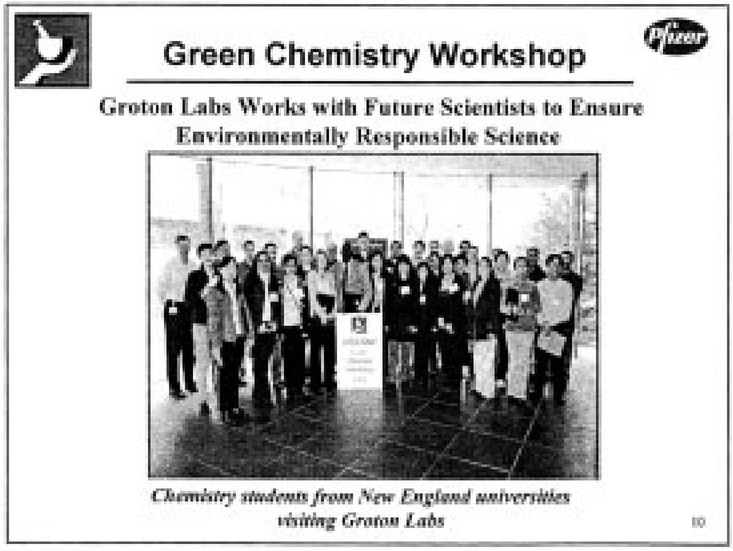
Call for nominations!

Refer to the *Pipeline* article on July 7, 2003 for full details.

Submit nominations to Michael Kettas via e-mail or interoffice mail (MS 4157) no later than October 31, 2003.

Let me now address the question of impediments-focusing on three that are important to our industry.

1. **Academic training:** Today, there are very few students graduating with chemistry majors who are trained in or even exposed to green chemistry. In the slide shown now we are investing a huge amount of energy to educate our scientists about the green chemistry principles and how they apply to our daily R&D efforts. We would be in a much better place if the chemists who joined our company were practicing green chemistry on the first day of work. In addition to active education we sponsor R&D site based awards to encourage green chemistry. In addition to a trophy and public recognition the recipients are awarded a cash prize, with the stipulation that they donate it to a college or university of their choice to encourage green chemistry education. The legislation you are considering today should help support more focus on green chemistry education at the college and university levels. There are a few schools that do this very well today: U. Mass.-Boston, Carnegie Mellon, University of Alabama, Washington State University, to mention some of them. More are needed.



Green Chemistry Workshop

Groton Labs Works with Future Scientists to Ensure Environmentally Responsible Science

Chemistry students from New England universities visiting Groton Labs

To address this issue Pfizer has begun a program of reaching out to universities near our R&D sites to host symposia where students are exposed to green chemistry in real life case studies. They leave with a better understanding of how chemistry is practiced in the pharmaceutical industry and how green chemistry contributes to R&D success.

Another potential barrier to companies in our industry pursuing green chemistry solutions is the need to pay strict attention to the purity profile of the drugs we produce. By definition, an active pharmaceutical ingredient (API) is the active chemical and its normal process related substances (PRS's). This profile is established as part of the R&D process and is "qualified" as part of our preclinical animal safety studies and human clinical development experience. This profile is described in our regulatory submissions (New Drug Application in the U.S.) and establishes the ranges for our product quality specifications. Changes in the manufacturing processes can create new process-related substances, easily detectable using modern analytical tools. Presence of these new PRS's at higher than allowed levels could necessitate redoing significant portions of development work, a time-consuming expensive and risky proposition. Every company has instances where processes which produce higher yields of cleaner product with a much better environmental profile, but were not pursued further because of this barrier. Obviously, using green chemistry earlier will lessen, but not remove this risk. In this case the goal of the FDA and the EPA may not always be mutually compatible. It is very important that we retain the flexibility to make business decisions that weigh and balance business risks with potential benefits.

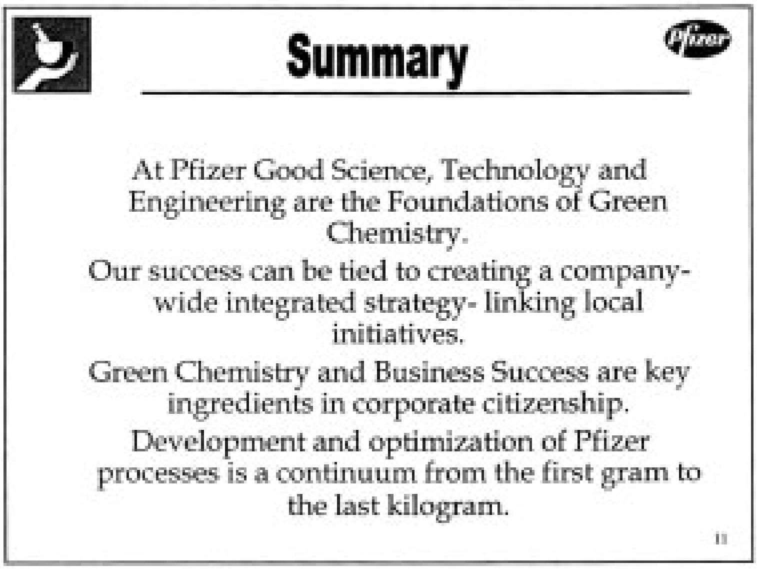
One issue that has repeatedly surfaced in green chemistry discussions is whether consumers will pay for environmentally benign products. The consensus is that they will not.

Executive Order 13101 was signed in September 1998. In section 102, it states, "consistent with policies established by the Office of Federal Procurement Policy (OFPP) agencies will comply with executive branch policies for the acquisition and use of environmentally preferable products and services and implement cost-effective procurement preference programs favoring the purchase of these products and services.

We believe that companies that produce products derived from manufacturing processes consistent with green chemistry principles should qualify for consideration under this Executive Order.

As to the question of this specific legislation our experience teaches that an integrated approach to green chemistry at Pfizer that coordinates the efforts of R&D, Manufacturing and EH&S is a more effective way to create an effective green chemistry strategy. Prior to this we had a series of unconnected tactics, with no guarantee that we were gaining maximum benefit or that we were not seeing unnecessary duplication of effort.

The proposed legislation establishes a Green Chemistry R&D Program to promote and coordinate federal green chemistry research, development, demonstration, education, technology transfer and commercial application activities. These are all critical components of Pfizer's successful green chemistry initiative. The availability of merit-reviewed competitive grants to support academic programs and to promote education and training of undergraduate and graduate students in green chemistry should help address the issue of lack of adequate green chemistry programs in academic institutions. The charge to the Federal Government to create incentives for use of green chemistry products and processes should help to address the issue I raised with respect to Executive Order 13101. Of specific interest to the Pharmaceutical industry would be the working relationship between this inter-agency group and reviewing chemists at the Food and Drug Administration. We believe that the levels of appropriation are appropriate for the initiation and sustaining of this program over the 2005–2007 timeframe.



Summary

At Pfizer Good Science, Technology and Engineering are the Foundations of Green Chemistry.

Our success can be tied to creating a company-wide integrated strategy- linking local initiatives.

Green Chemistry and Business Success are key ingredients in corporate citizenship.

Development and optimization of Pfizer processes is a continuum from the first gram to the last kilogram.

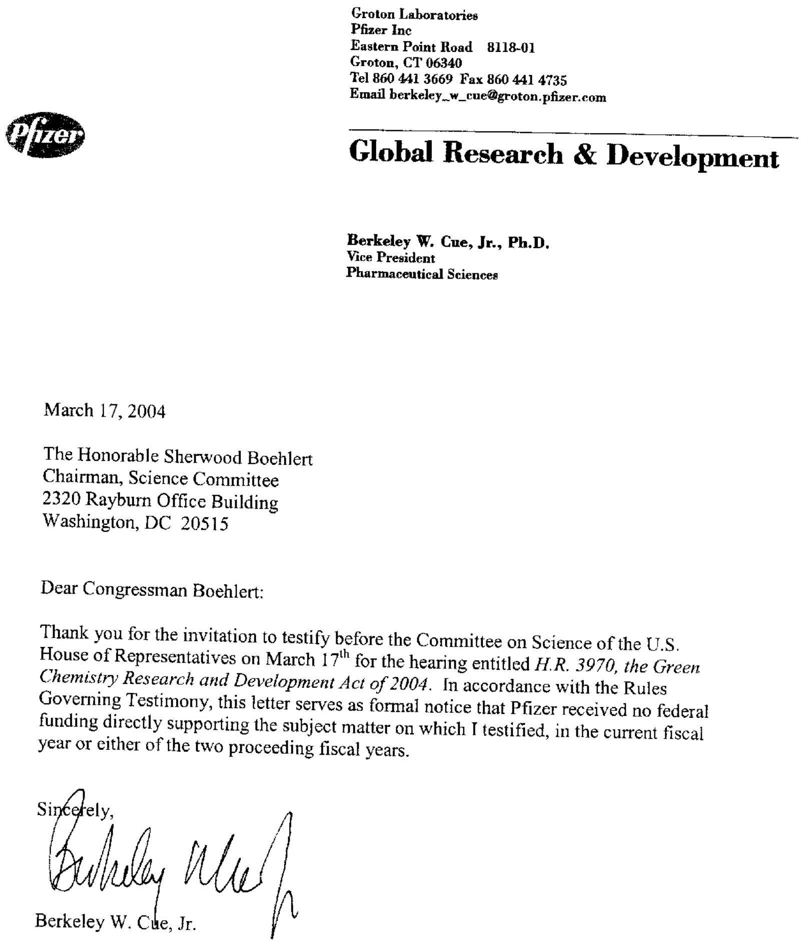
In closing I would like to thank the Committee for your attention. Green chemistry has the potential to produce the greatest change in the way synthetic chemistry is practiced in the last quarter century. It is already redefining how chemistry is thought about and practiced at every stage of R&D and commercial manufacture at Pfizer.

My crystal ball is no better at discerning the future than anyone's, but my prediction is that at some time in the future a Nobel Prize in Chemistry will be awarded to a green chemist. Our CEO, Dr. Hank McKinnell is fond of telling Pfizer employees, "the patient is waiting." In this context, it is clear that our environment is waiting too.

Thank you again for the opportunity to appear before you today and discuss Pfizer's Green Chemistry initiatives and the proposed legislation.

BIOGRAPHY FOR BERKELEY W. CUE, JR.

At Pfizer Dr. Cue is responsible for the departments (Analytical R&D, BioProcess R&D, Chemical R&D, Pharmaceutical R&D, Regulatory CMC and Pharmaceutical Sciences Business Operations) that comprise Pharmaceutical Sciences. He was a member of the Worldwide Pharmaceutical Sciences Executive Team, and the Groton Laboratories Leadership Team. He also leads Pfizer's Green Chemistry Initiative and has spoken extensively on this topic since 2000. Dr. Cue started in Pfizer in 1975 in the Animal Health Organic Chemistry Department. He transferred to the Process R&D Department of Developmental Research in 1979. Became head of the PR&D Department in 1988 assumed responsibility for Analytical and BioProcess R&D as well in 1993 and US Developmental Research in 1998. Chaired the CVMD EDMT (1998–1999) and co-chaired the division's Performance Management Task Force (1992–1993). He received a BA from the University of Massachusetts-Boston (1969), his Ph.D. (Organic Chemistry) from the University of Alabama (1974), and completed Postdoctoral Research at the Ohio State University (1974), National Cancer Institute Research Fellow, University of Minnesota (1975). In 2000 he was appointed to the Science Advisory Board at the University of Massachusetts-Boston. In 2003 he was elected to the Green Chemistry Institute Board of Directors. Dr. Cue will retire from Pfizer in 2004 after almost 29 years. He intends to remain active in Green Chemistry through his affiliations with the Green Chemistry Institute and the University of Massachusetts-Boston.



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Global Research & Development

Berkeley W. Cue, Jr., Ph.D.
Vice President
Pharmaceutical Sciences

March 17, 2004

The Honorable Sherwood Boehlert
Chairman, Science Committee
2320 Rayburn Office Building
Washington, DC 20515

Dear Congressman Boehlert:

Thank you for the invitation to testify before the Committee on Science of the U.S. House of Representatives on March 17th for the hearing entitled *H.R. 3970, the Green Chemistry Research and Development Act of 2004*. In accordance with the Rules Governing Testimony, this letter serves as formal notice that Pfizer received no federal funding directly supporting the subject matter on which I testified, in the current fiscal year or either of the two proceeding fiscal years.

Sincerely,

Berkeley W. Cue, Jr.

Chairman BOEHLERT. Thank you, Dr. Cue. Pfizer has a good story to tell in its responsible approach to this subject, and I appreciate your telling it exceptionally well.

For the purpose of introduction, I recognize the author of the bill and a leading voice in the Congress, Dr. Gingrey.

Mr. GINGREY. Thank you, Mr. Chairman.

I am very pleased to—actually to reintroduce Mr. Steve Bradfield from Shaw Industries in Georgia. And Steve, I understand your son is with you today, is that correct? Can he raise his hand? His name is——

Mr. BRADFIELD. Drew.

Mr. GINGREY.—Drew. We welcome you, too, Drew.

Steve has been with Shaw Industries since 1991 and currently serves as Vice-President of Environment Development. And I am proud to have Shaw Industries in my home state, Whitfield County, Dalton, Georgia. It is not quite in my 11th Congressional District, but I am still working on that. Shaw won a 2003 Presidential Green Chemistry Challenge Award for the development of EcoWorx™, carpet tile that is made from low-toxicity feedstocks and is recyclable. Steve conceived and led that effort and continues to push Shaw's model cradle-to-cradle environmental statement throughout Shaw Industries. And I look forward to hearing from his expertise and experience on green chemistry.

Thank you, Mr. Chairman.

Chairman BOEHLERT. Thank you, Dr. Gingrey. That is a great introduction. And I am glad, Mr. Bradfield, that you brought Drew with you, because that is the very corner in our society that we are really anxious to get excited about this. So I am glad to hear him listening with wrapped attention to our witnesses.

Mr. Bradfield.

STATEMENT OF MR. STEVEN BRADFIELD, VICE PRESIDENT OF ENVIRONMENTAL DEVELOPMENT, SHAW INDUSTRIES, INC.

Mr. BRADFIELD. I would like to think, Mr. Chairman, that he is just enthralled by this, but I think the prospect of getting out of school for a couple of days was what swung him my way.

Congressman Gingrey, Mr. Chairman, and Committee Members, it is an honor to be invited to share my comments with you today on the *Green Chemistry Research and Development Act of 2004.* I am here more on the capacity of representing the industry today, quite frankly. I would like to make comments on the behalf of the Carpet and Rug Institute, and the many carpet members who are making such important strides, as well as Shaw, in this area. I have been asked to speak and communicate the outstanding efforts and collective comments of the industry in the area of green chemistry and sustainability.

Good carpets begin with good chemistry. Over the years, our industry has consistently made changes to promote human and environmental health and safety. We did this before green chemistry and sustainability became watchwords for a very simple reason: it increased the desirability of carpet in the eyes of our customers and provided—and improved our profitability. Customer demand and profitability are the most enduring drivers of green chemistry and sustainability, without a doubt.

Green chemistry has long been valued by the industry. Since 1992, the CRI has administered a voluntary indoor air quality program, known as Green Label Certification. It is a cooperative effort between the carpet industry and its suppliers to eliminate and reduce chemicals of concern to levels that are far below the volatile organic compound emission rates of other interior building finishes. No other building material industry has committed this level of resources or achieved as much progress in indoor air quality improvement.

With this experience in mind, we urge the Interagency Working Group to work closely with industry to set ambitious and realistic goals for ongoing green chemistry programs. It is often easy to lose sight of the value vested in the "willing," those who take up the challenge to develop materials that extend the reach of green chemistry, while the "unwilling" remain anonymous and untouched by the effort to create a sustainable environment for our children. We are not suggesting penalties for the faint of heart. We believe that rewarding those that commercialize green chemistry developments with research and development grants, tax incentives, and preferential federal purchasing programs will drive the desired advances in green chemistry, in addition to the bill before you.

To those of us in the manufacturing sector, green chemistry implies developments that are robust, that are additive to the value we bring to our markets, and are highly implementable. We believe green chemistry should be defined to include materials and process development. It should include pollution prevention that moves us to the paradigm of becoming "less bad" in the near term, but should look forward to the longer term development of "closed-loop" systems that can help us eliminate the very concept of waste.

The carpet industry believes that green chemistry will proceed along two major pathways: nature's organic path, and man's synthetic/technical path. Both are valid and offer a variety of promising discoveries and inventions. Bio-chemicals and biopolymers offer exciting possibilities for agriculture and industry. Meanwhile, our continued reliance on oil-based materials assures that the resulting waste will be available as recyclable feedstock for synthetic closed-loop processes.

Our industry has many commercialized examples of green chemistry at work. On the fiber side, Mohawk Industries and Beaulieu of America are taking post-consumer polyester drink bottles, which we have before you today, processing them into flake, and then remelting and extruding the material into polyester carpet fiber, ready for spinning, dying, and tufting into residential carpet. Honeywell has developed a technology to recover the caprolactum monomer building block of nylon 6 from post-consumer carpet. Invista collects post-consumer carpet and sends the dyed nylon into recycled uses, such as extrusion molded under hood car parts and geotextiles. Dow Cargill has developed a bio-based fiber, called polylactic acid, from corn. It is now being evaluated for residential carpet.

We believe that industry has a valid role in helping to define a practical research and development agenda. We respectfully suggest that the Interagency Working Group undertake a survey of current environmental programs within the Federal Government to bring them up to date with the broad range of sustainability characteristics that will be impacted by green chemistry developments. These impacts are being defined and clarified through the use of life cycle analysis. Reliance on single environmental metrics, like recycled content, may actually result in a disincentive to green chemistry development in many circumstances. First generation polymers usually can not contain significant recycled content until a value recovery system returns them to second-generation manufacturing.

New materials and processes are beginning to take root in our industry. Many carpet companies are recognizing that traditional thermoset materials can be replaced by thermoplastics, facilitating the recovery, re-melting, and re-extrusion of tried and true materials, like vinyl. Collins & Aikman and Interface have developed systems for returning vinyl carpet tile backing to their backing processes. And as has been mentioned, Shaw was recognized for the 2003 Presidential Green Chemistry Award for developing a thermoplastic polyolefin carpet backing. The CRI Annual Sustainability Report includes many other industry developments and practices that reduce the environmental footprint of carpet through green chemistry.

The Carpet America Recovery Effort, which is a nonprofit effort, including the carpet industry, the Federal EPA, state governments, and NGOs with the goal of diverting 40 percent of landfill waste by 2012, a very ambitious goal. Imagine a future when no carpet goes to a landfill but is separated into its constituent parts at the end of its useful life to be sustainably recycled over and over again. This is happening today with some carpet types, but not enough as yet is being diverted to significantly reduce the 4.5 billion pounds of carpet that reaches our landfills today. Green chemistry can help develop beneficial uses for these materials.

Perhaps the most compelling reason to support green chemistry and the growth of sustainable materials and processes in carpet is jobs. Annual carpet production and consumption in the U.S. of $12 billion is equal to the rest of the world carpet production and consumption combined. Carpet jobs will stay in the U.S. if we can develop ways to keep post-consumer carpet material in sustainable closed-loop recycling systems that reduce the need for virgin raw materials and lower the energy embodied in successive generations of carpet. Why would any U.S. company choose to manufacture overseas if their valuable raw materials are being collected and recycled at lower cost, with no sacrifice of performance from American homes and businesses in close proximity to the means of production?

The economic benefits of green chemistry are quantifiable in each of the examples given herein. As an industry, green chemistry has helped to reduce the water required for dying a square yard of carpet from 14.9 gallons in 1995 to 8.9 gallons in 2002. The energy requirement for thermal fuels used to make a square yard of carpet have fallen from 14.5 million BTUs in '95 to 10.3 million BTUs in 2002. Today, the carpet industry has the same level of CO_2 emissions it reported in 1990, yet it produces 47 percent more carpet.

Shaw's experience with green chemistry is representative of the developments that are ongoing in the industry. By way of illustration, Shaw's polyolefin carpet tile backing has fueled an average growth rate in Shaw carpet tile of almost 15 percent per year over the last four years. This growth provides 440 jobs in our Cartersville, Georgia carpet tile facility and generates over $100 million annually in revenue. It has reduced packaging costs by 70 percent, shipping costs by 20 percent, and resulted in over $100,000 in annual post-industrial scrap recovery. The recovery of the post-consumer carpet tile will result in even more savings in the second generation.

I brought some materials that have contributed to the success of this program, and with your indulgence, I am running a little later than most, but I would encourage you to take a look at these as you can. What I have for you here is basically recycled content nylon and metalacene catalyzed polyolefin. And gentlemen, these things will be very difficult to see from afar, but if you would like for someone to bring them up for you, I would be glad to do that. In addition——

Chairman BOEHLERT. Perhaps your associate, Mr. Bradfield, Drew Bradfield, could bring them up, and we could pass them around?

Mr. BRADFIELD. Drew would be more than happy to. We seem to have somebody who is coming up now. I can't get him to do anything at home, either, by the way.

Fully oxidized fly ash is one of the components that replaces virgin limestone, which is mined from the Earth. Post-consumer polyethylene from plastic bag waste, the post—and the post-consumer carpet tile processed into two raw material streams, the nylon stream to be depolymerized by nylon and returned to nylon production, and a polyolefin backing stream to be returned to backing extrusion. The point here is that what you have in your hands moving around is the entire carpet tile. None of these materials need ever reach a landfill if consumers will take advantage of the value recovery system at the other end of the toll-free number imprinted on the back of every carpet tile we ship.

Other manufacturers share similar economic stories that are just as compelling. I have brought some other materials here. This is post-consumer polyester bottle flake.

Chairman BOEHLERT. Appropriately green.

Mr. BRADFIELD. Appropriately green today, so I don't get pinched. This clear version of this material, which would be from the bottle that we have here in front of us, can be used, as I said, to make polyester fiber for carpet. This green material has been problematic over the years, because there has not been a use. However, we have been able to spin this into fiber and make it into a carpet padding, which can be attached to the back of a carpet in today's market.

In conclusion, the carpet industry supports the adoption of the *Green Chemistry Research and Development Act of 2004* with the suggestions that Congress encourage a cooperative effort among government, academia, and business, that Congress seek additional incentives to reward companies, large and small, that commercialize green chemistry developments, that obstacles to the green chemistry process be removed from current federal environmental programs, and that adoption of green chemistry in the broader context of sustainable product development should become a primary instrument of pollution prevention policy. These goals are worthy of our collective investment of time, treasure, and talent. Distinguished Committee Members, I brought my 17-year-old son, Drew, with me here today from Dalton to let him know that it is his future, and his world, that will benefit from our efforts. I hope someday he may sit where you are, or where I am, with your sons and daughters to push green chemistry to greater levels of success than we can imagine here today.

Thank you.

[The prepared statement of Mr. Bradfield follows:]

PREPARED STATEMENT OF STEVE BRADFIELD

Mr. Chairman and Committee Members, it is an honor to be invited to share my comments with you today on the *Green Chemistry Research and Development Act of 2004.* I represent the fiber, carpet, and rug manufacturer members of the Carpet

& Rug Institute, headquartered in Dalton, GA, as Chairman of Sustainability Issues. I have asked to speak in this capacity to communicate the outstanding efforts, and collective comments, of our industry members is the area of green chemistry and sustainability.

The carpet industry is one of the last bastions of US textile manufacturing. Our industry has maintained its long-standing relationships with the communities where we've lived and worked for four generations, and we intend to keep doing so. We've largely accomplished this through the development of material and process technologies that have resulted in continuous improvements in the value of soft floor covering. *Technology development is the lifeblood of our industry.*

Good carpets begin with good chemistry. Over the years our industry has consistently made changes that promote human and environmental health and safety. We did this before green chemistry and sustainability became watchwords for a very simple reason—it increased the desirability if carpet in the eyes of our customers and improved profitability. *Customer demand and profitability are the most enduring drivers of green chemistry and sustainability.*

While it can be argued that many environmental improvements date from 1985 with the advent of Toxic Release Index reporting, far more improvements have been driven by market forces. The permanence and efficiency of positive change driven by a free market cannot be underestimated. *No regulations could have moved our industry so far and so fast in the direction of sustainable development.*

Green chemistry has long been valued by our industry. Since 1991 the CRI has administered a voluntary indoor air quality program know as Green Label Certification. It is a cooperative effort between the carpet industry and its suppliers to eliminate and reduce chemicals of concern to levels that are far below the volatile organic compound emission rates of other interior building finishes. *No other building material industry has committed this level of resources or achieved as much progress in indoor air quality improvement.*

We've raised the bar in the Green label Program three times since 1991 and will soon raise it yet again to meet our pledge of continuous improvement and leadership on this green chemistry issue. But as with any voluntary program, these improvements are never fast enough or far enough to satisfy all stakeholders. *We strongly urge the Interagency Working Group to work closely with industry to set* ambitious *and* realistic *goals for ongoing green chemistry programs.*

It is often easy to lose sight of the value vested in the "willing," those who take up the challenge to develop materials that extend the reach of green chemistry, while the "unwilling" remain anonymous and untouched by the effort to create a sustainable environment for our children. We are not suggesting penalties for the faint of heart. *We believe that rewarding those that commercialize green chemistry developments with research and development grants, tax incentives, and preferential federal purchasing programs will drive the desired advances in green chemistry.*

We also encourage this committee to acknowledge the broad range of activities encompassed by green chemistry. *To those of us in the manufacturing sector green chemistry implies developments that are robust, additive to the value we bring to our markets, and highly implementable.* We believe green chemistry should be defined to include materials and process development. It should include pollution prevention in the classic sense of moving us toward the paradigm of becoming "less bad" in the near-term, but should also look forward to the longer-term development of "closed-loop" systems that move us into the "environmentally good" paradigms that allow us to mimic Mother Nature. *Green Chemistry can help us to eliminate the very concept of waste.*

The carpet industry believes that green chemistry will proceed along two major pathways—nature's organic path, and man's synthetic/technical path. Both are valid and offer a variety of promising discoveries and inventions. Bio-chemicals and biopolymers offer exciting possibilities for agriculture and industry. Meanwhile, our continued reliance on oil-based materials assures that the resulting waste will be available as recyclable feedstock for synthetic closed-loop processes.

Our industry has many commercialized examples of green chemistry at work. On the fiber side Mohawk Industries and Beaulieu of America are taking post-consumer polyester drink bottles, processing them into flake, and remelting and extruding the material into polyester carpet fiber ready for spinning, dyeing, and tufting into residential carpet. Honeywell has developed a technology to recover the caprolactam monomer building block of nylon 6 from post-consumer carpet. Invista collects post consumer carpet and sends the dyed nylon into recycled uses such as extrusion molded under hood auto parts and geotextiles. Cargill Dow has developed a bio-based fiber called polylactic acid from corn that is now being evaluated in residential carpet

While universities, laboratories, and other basic research paths are a precursor to many of the applications of green chemistry that will find their way into our facilities, basic research alone will not change the way we manufacture and consume products. How will the research and development dollars granted by the agencies specified in the House Bill find their way into real solutions to real problems that face all Americans? How will priorities be established? *We believe industry should have a voice in defining the research and development agenda.*

We respectfully suggest that the Interagency Working Group undertake a survey of current environmental programs within the Federal Government to bring them up to date with the broad range of sustainability characteristics that will be impacted by green chemistry developments. These impacts are being defined and clarified through the use of life cycle analysis. Reliance on single environmental metrics like recycled content may provide a disincentive to green chemistry development in many circumstances. *First generation polymers usually cannot contain significant recycled content until a value recovery system returns them to second-generation manufacturing.*

New materials and processes are beginning to take root in our industry. Many carpet companies are recognizing that traditional thermoset materials can be replaced by thermoplastic materials—facilitating the recovery, remelting, and re-extrusion of tried-and-true materials like vinyl. Collins & Aikman and Interface have developed systems for returning vinyl carpet tile backing to their backing processes. Shaw was recognized with the 2003 Presidential Green Chemistry Award for developing a thermoplastic polyolefin carpet tile backing. The CRI Annual Sustainability Report includes many other industry developments and practices that reduce the environmental footprint of carpet through green chemistry (see *www.carpet-rug.com*).

The Carpet America Recovery Effort (CARE) is a nonprofit effort including the carpet industry, the Federal EPA, State governments, and NGO's with the goal of diverting 40 percent of carpet landfill waste by 2012 (see *www.carpet-recovery.com*). Imagine a future when no carpet goes to a landfill, but is separated into its constituent parts at the end of its useful life to be sustainably recycled over and over again. This is happening today with some carpet types, but not enough as yet to significantly divert the 4.5 billion pounds of carpet that went to our nation's landfills in 2003. *Green chemistry can help to develop beneficial uses for the materials used to make carpet today and assure that steady progress is made toward sustainable materials that can go directly back into carpet production in the future.*

Perhaps the most compelling reason to support green chemistry and the growth of sustainable materials and processes in carpet is jobs. Annual carpet production and consumption in the U.S. of $12 Billion is equal to the rest of world carpet production and consumption combined. Carpet jobs will stay in the U.S. if we can develop ways to keep post-consumer carpet materials in sustainable closed-loop recycling systems that reduce the need for virgin raw materials and lower the energy embodied in successive generations of carpet products. *Why would any U.S. company choose to manufacture overseas if their valuable raw materials are being collected and recycled at lower cost, with no sacrifice of performance, from American homes and businesses in close proximity to the means of production?*

The economic benefits of green chemistry are quantifiable in each of the example given herein. As an industry, green chemistry has helped to reduce the water required for dyeing a square yard of carpet from 14.9 gallons in 1995 to 8.9 gallons in 2002. The energy required from thermal fuels to make a square yard of carpet has fallen from 14.5 million BTU's in 1995 to 10.3 million BTU's in 2002. Today the carpet industry has the same level of CO_2 emissions it reported in 1990 yet it produces 40 percent more carpet.

Shaw's experience with green chemistry is representative of the developments that are ongoing in the industry. By way of illustration, Shaw's polyolefin carpet tile backing has fueled an average annual growth rate in carpet tile of almost 15 percent per year over the last four years. This growth provides 440 jobs in our Cartersville, Georgia carpet tile facility and generates over $100 million in revenue. It has reduced packaging costs by 70 percent, shipping costs by 20 percent, and resulted in over $100,000 in annual post-industrial scrap recovery. The recovery of the post-consumer carpet tile will result in even more second-generation savings. *Other manufacturers can share economic success stories that are just as compelling.*

In 1950 the carpet industry shipped 97 million square yards of carpet. In 2001 we shipped 1.879 billion square yards. Between 1965 and 2001 carpet increased in price by 90.4 percent while the same time period saw an automobile increase 180.4 percent and a combined total of all commodities increased 315.4 percent. Over 80 percent of the U.S. carpet market is supplied by mills located within a 65-mile radius of Dalton, Georgia. *Carpet is important to the economy of Georgia and the United States. Green chemistry is an important tool to facilitate its continued growth.*

In conclusion, we support the adoption of the *Green Chemistry Research and Development Act of 2004* with the suggestions that Congress encourage a cooperative effort among government, academia, and business; that Congress seek additional incentives to reward those companies that commercialize green chemistry developments; that obstacles to the green chemistry discovery process be removed from current federal environmental programs; and that adoption of green chemistry in the broader context of sustainable product development should become a primary instrument of pollution prevention policy in the United States with the additional goals of job creation and economic improvement.

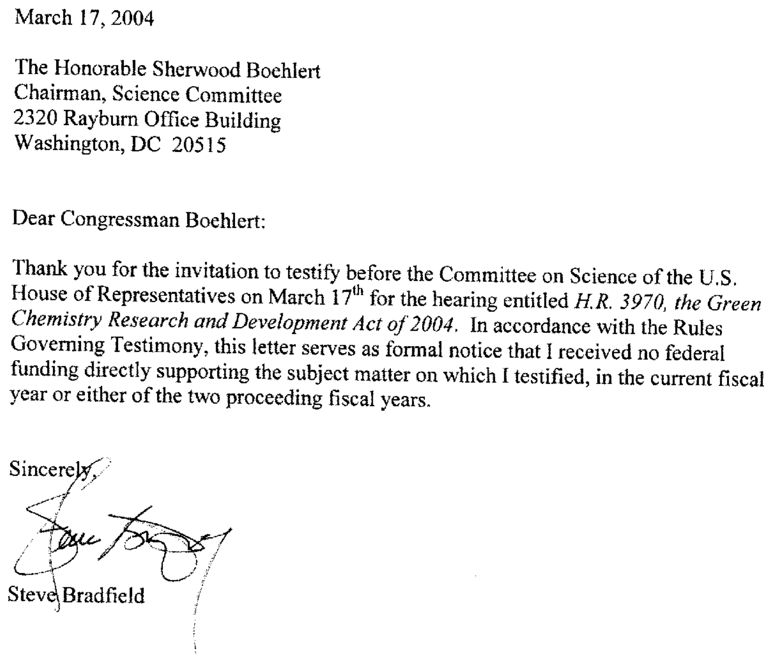
BIOGRAPHY FOR STEVEN BRADFIELD

Steve Bradfield began his career in the commercial carpet industry twenty years ago gaining experience in sales, marketing, and technical and environmental development. He has been with Shaw Industries since 1991 in both international and U.S. positions and is currently VP of Environmental Development.

Steve leads Shaw in its journeyman development of customer-oriented cradle-to-cradle solutions to environmental concerns. He is active with the USGBC, the CARE Executive Committee, TFM Green Advisory Board, and the CRI Market Issues and Sustainability Committees. Steve conceived and led the effort to develop the 2003 EPA Presidential Green Chemistry Challenge Award winning EcoWorx polyolefin carpet tile backing at Shaw and continues to push Shaw's model cradle-to-cradle environmental statement throughout Shaw Industries. He has written many articles on sustainability for periodicals, including the peer-reviewed *Environmental Science & Technology* journal, and recently completed an interview with Michael Toms aired on National Public Radio as part if the "Monticello Dialogues."

He is a graduate of Montana State University at Bozeman and considers himself an adventurous seeker of change. Early experiences as an archaeological dig volunteer, a deck hand on a tugboat on the Mississippi River, a roustabout on an offshore oil rig in the Gulf of Mexico, a cowboy on a Wyoming Ranch, and three years in strip mining coal in Southern Montana, have given him a unique perspective on environmental responsibilities and a passion for sustainable development. Steve is deeply committed to market-based implementation of industry-leading environmental technologies.

Steve has traveled extensively all over the world in designing and marketing carpet and considers himself fortunate to have a much broader perspective of the diversity of the people and markets outside the U.S. However, enough is enough, and he is well pleased to now concentrate full time on opportunities for Shaw in environmental development in the U.S. He has been married to his wife, Christy, for twenty-five years, and has three teenage children that constantly challenge and delight him. Life is good, and getting better.



March 17, 2004

The Honorable Sherwood Boehlert
Chairman, Science Committee
2320 Rayburn Office Building
Washington, DC 20515

Dear Congressman Boehlert:

Thank you for the invitation to testify before the Committee on Science of the U.S. House of Representatives on March 17th for the hearing entitled *H.R. 3970, the Green Chemistry Research and Development Act of 2004.* In accordance with the Rules Governing Testimony, this letter serves as formal notice that I received no federal funding directly supporting the subject matter on which I testified, in the current fiscal year or either of the two proceeding fiscal years.

Sincerely,

Steve Bradfield

Chairman BOEHLERT. Thank you very much, Mr. Bradfield. And as the audience will note, we allowed you some extra time to go on, because I thought it was very important that we get this perspective from an industry guy, because so often what we do up here is viewed by those outside Washington, DC as anti-business, anti this and anti that. That is all a bunch of nonsense. I mean, we are trying to—we recognize that the business community is the engine that drives the economy, and we want to work with you and so that you won't think that Mr. Bradfield is just another guy from industry, let me read a little bit here. "Early experiences as an archaeological dig volunteer, a deck hand on a tugboat on the Mississippi River, a roustabout on an offshore oil rig in the Gulf of New Mexico, a cowboy on a Wyoming ranch, and three years of strip mining coal in Southern Montana have given him a unique perspective on environmental responsibilities and a passion for sustainable development." My one question of you is would you let Drew follow that same career path? And I won't ask for an answer right now, Mr. Bradfield.

Now for words of wisdom from Troy, New York, it is my pleasure to introduce, from Renssalaer Polytechnic Institute, one of America's great institutions, Dr. Woodhouse.

STATEMENT OF DR. EDWARD J. WOODHOUSE, ASSOCIATE PROFESSOR OF POLITICAL SCIENCE, DEPARTMENT OF SCIENCE & TECHNOLOGY STUDIES, RENSSELAER POLYTECHNIC INSTITUTE

Dr. WOODHOUSE. Thank you, Chairman Boehlert and Members of the Committee. I appreciate the opportunity to think with you this morning about what I see as an historic undertaking. It is very seldom that one finds the kind of vision and long-term hope that I see embodied in this bill, and I congratulate you for it. That is not to say I don't have a few recommendations to improve it.

I am a political scientist, not a chemist. I have, over the past generation, made inquiries into what goes right and what goes wrong with a wide variety of technological endeavors: civilian nuclear power, pesticides, premanufacture notification for new chemicals, ozone depleting chemicals, presently nanotechnology and robotics, and a variety of other topics. My graduate students and I have been studying the green chemistry community for about seven years, trying to understand what the social barriers are to the implementation of the—of their findings and what slows down the movement of new ideas within the worlds of chemistry and chemical engineering themselves. So I want to just say a little bit about that, not because it has direct impact on your pending legislation, but because it may be of some use to you as you go forward in a variety of fronts on this over the next decade and more.

The one thing that I have found in every area that I have looked at is that we radically underestimate the technical malleability, the capacity of engineers and other technical people to work with the stuff of the world in creative ways. Always under-estimated. We over-estimate the extent of which we have our social purposes lined up for the technical people to serve. So that whereas the technical capacities could be utilized for fantastic purposes rarely do they come anywhere close to what would be possible, because we don't have the political, social, and economic institutions and processes that will catalyze that, as well as could be achieved.

Let me give an example. This morning, many of you started with decaffeinated coffee. How do they get the caffeine out of those beans? Well, it turns out that it is green chemistry. The supercritical carbon dioxide, which was mentioned by Dr. Bement, is a powerful solvent under the right conditions and can literally strip the caffeine out of the coffee bean, leaving the bean intact. The basic understandings about supercritical carbon dioxide are now approximately a century old. Why has it taken this long to move it into any purposes more important than decaffeinating coffee? That is a social mystery, not a technical one, primarily.

Another example. There was a mention of the dry cleaning industry and the work being done at the University of North Carolina. Excellent work. If you sniff your suits or sweater when it comes back from the dry cleaners, you will notice a faint chemical odor. That is perchloroethylene, PERC, which is used as the solvent. It is extremely toxic. It is one of the main toxic constituents of urban air pollution. A day care center near me had to be closed recently, because it was located too near a dry cleaners. The children and the teachers were getting ill. Each time an employee opens the dry cleaning machinery, they get a sniff of that chemical.

There is now a substitute: supercritical carbon dioxide. David Price, one of your colleagues, introduced legislation several years ago, which would have given tax credits to dry cleaners for switching over to the new equipment. In the Omnibus tax legislation of several years ago, that measure didn't make it out of Committee. The—one of the reasons—there were financial and other prudential reasons, no doubt, but one of the reasons was the Committee's staff and Members heard from not one interest group, not one constituent by phone, letter, or personal visit. The issue is simply not on the radar screen. And hence, what could have been a simple move to encourage mom and pop dry cleaners, who need the economic assistance if they are to shift away from a dangerous practice, they didn't get the help, they still don't have the help, even though the machinery is on the market. That is not atypical. I recognize it is outside the jurisdiction of this committee, but it is important to realize the social barriers, I think, and that is one of them.

More generally, we have been interviewing green chemists around the world, and they say, over and again, that it is economic inertia and professional inertia that are the main barriers; it is not technical understanding and scientific uncertainty, although those play a role. Rohm and Haas, for example, has developed a biodegradable, water-soluble polymer, which would go in laundry detergent. It costs twice as much as the one now utilized. It is not being used. I asked the relevant person, "Well, how much would it cost the consumer?" They said about one penny per bottle of detergent. $4.01 instead of $4. That is a lot of money, though, to Proctor and Gamble, probably $1 million a year, if you would figure out the number of bottles they sell. We need some way to figure out how to do what is sensible at that level. It is a mundane practice, not nearly as glorious as many of the research projects discussed here today. But that is a—that is the reality. Mattel promised to take polyvinylchloride out of their Barbie dolls. They recently reneged on that promise, despite the fact that Bayer Chemical provides an alternative, which would cost only five percent more. You know what the cost of plastic in a Barbie doll is relative to the sales price. It is a trivial amount, and yet, it is not being utilized.

Professional inertia is almost as bad as economic inertia. If you think about the professors that you had who were using old lecture notes, not keeping up to date, you will have some idea of what I mean. The curricula at a major university near here, there is a one-credit course in green chemistry as the sole offering in the curriculum. Another department chair told me, "There is no room in the curriculum." Another said he tried to get the changes, but his faculty said, "That is not the way it is done at Harvard and Chicago." They require foreign languages at half of the American universities to get a Ph.D. in Chemistry, but no one requires a test in toxicology. A green chemist, not me, referred to what is going on as "stupid chemistry," "just bad design," "profound failure."

I will conclude by just suggesting that the task, then, is larger than what can be done by a few million dollars for more research. None of us knows exactly how to bring it about. What we can do is to catalyze an inquiry and a discussion that aims for "benign by design." Let us figure out how to use those tremendous technical potentials so that we aim to make each chemical safe enough for living things. I believe that that is chemically possible, even though most chemists today would say it is not.

In conclusion, I have a couple of recommendations for your consideration. First, tax credits. The industry, we don't expect to get ice cream for free, why should we expect to get green chemistry for free? Contrary to what some of my colleagues on the panel have said, I believe there is a limit to what you can do that will actually make money. I think that some things do cost money. We need to figure out how to make that sensible for all parties concerned.

Secondly, more precise requirements in the reports that you are asking for under this legislation. There is too much room for interested parties to make self-serving statements. Let us get some devil's advocates into the process who will look more closely at the claims, who will attempt to bring the stakeholders into communication, shall we say, with each other.

Finally, I would suggest that you consider the possibility of tilting the funding more towards EPA. In my experience, the EPA Pollution Prevention Program is one of the best things that the Federal Government does.

Thank you very much.

[The prepared statement of Dr. Woodhouse follows:]

PREPARED STATEMENT OF EDWARD J. WOODHOUSE

Chairman Boehlert, Ranking Member Gordon, and Members of the Committee, I thank you for inviting me to testify.

I am a political scientist interested in understanding how to shape technological decision-making more wisely. I have been studying the social aspects of green chemistry and green chemical engineering since 1998, funded in part by the National Science Foundation. My Ph.D. student, Jeff Howard, with funding from an EPA STAR fellowship, has been doing detailed interviews with green chemists, and I draw selected data and insights from his study.

My purpose here today is to discuss barriers and prospects for moving from what might be called "brown chemistry" toward a greener chemistry featuring chemicals designed to be benign or close to it. I will begin with general considerations I think Members of Congress should be taking into account, then present three simple categories of green chemistry and the legislative opportunities in each, and conclude with some suggestions for further study.

General Considerations

I start with a prediction: The 21st century will see the beginnings of a transnational phase out of chlorinated and other toxic synthetic chemicals. Economic considerations facing industry, slow-to-change university curricula in chemistry and chemical engineering, and citizens' ignorance about the potential for benign chemistry may delay the projected phase out well beyond the time period technically required. Evidence against toxic chemicals is accumulating relentlessly, however, and green chemistry and engineering potentials are developing, even if more gradually than one would wish. So the main question, it seems to me, is whether public policy will lead or lag.

I congratulate the Committee for its farsightedness in generating the proposed Green Chemistry Research and Development Program, and I regret to report that I find outside this room a certain timidity and lack of vision with respect to the subject. I am sorry to say that most professors of chemistry and chemical engineering appear to be either uninformed or uninterested, and a few are outright opponents who believe that toxicity is the price for what they would call "progress." Professional associations such as the American Chemical Society and the American Institute of Chemical Engineers are rhetorically supportive of chemical greening, and even have a few modest programs; but they are not doing much at present to actually inflect the trajectories of their mainstream members. Even environmental organizations such as Sierra Club could be doing a lot more: The National Toxics Campaign and other groups have been pushing for "clean production" and Zero Discharge, which bear on Green Chemistry but do not put it front and center—perhaps partly because their members resonate with whales, orangutans, and other charismatic megafauna more than with molecules.

Chemical technologies are highly malleable, however, and once it becomes widely understood that what we have been calling "chemistry" actually is a small and relatively backward subset of the chemical universe, the status quo will be on the defensive. The goal of a commendable chemical industry will be nothing less than to make everything using benign materials, and where toxicity cannot be avoided to draw on the services of medicinal and ecological chemists to design chemicals that rapidly decompose and are quickly excreted from living organisms. How closely that goal can be approximated, no one presently knows; what we can say for sure is that many technical achievements that seemed impossible have turned out not to be, in chemistry and in many other fields of science and engineering. With biocatalysis, nanochemistry, and other techniques not yet dreamed of but surely on the way, those who defend the 20th century's "brown chemical" way of doing things are pretty surely on the road to being discredited. Unless Congress intervenes, however, the transition could take many generations, with untold additional damage to living things around the world.

Everyone acknowledges that contemporary technologies for producing, using, and disposing of chemicals create numerous hazards, some of which result in damages that have to be mitigated or compensated at high cost. There is a sense in which present practices of the chemical industry resemble the "unfunded mandate" that the Federal Government sometimes is accused of leveling on states: Business-as-usual concerning chemicals makes little provision for medical payments to those affected (except for chemical workers), and little provision for environmental and other damages (except via insurance). As is true of health problems caused by tobacco, many such secondary and tertiary costs of chemical usage are picked up not by the industry itself, but by state and federal medical programs, by medical insurance companies, and ultimately by taxpayers and those who are privately insured. It may be misleading, therefore, to think of new regulations on the chemical industry as creating new costs; rather, costs would be shifted onto producers and users of chemicals—what economists refer to as "internalizing" such expenses by having them better reflected in prices. Tighter regulations would reduce or eliminate the present unfunded mandate that the chemical industry places on other businesses, government, and individual citizens.

It also is worth considering whether there is a commercial risk of waiting to act that may be greater for the chemical industry overall than any one element of it will have an interest in perceiving and acting upon. In particular, the Swedish Chemical Inspectorate already has a list of 250 suspect chemicals that probably are on their way out. The German chemical industry long has paid greater attention to labor, community, and other social interests than do most U.S. firms. Some Chinese technological universities are making a greater commitment to green chemistry than has any U.S. university to date. Altogether, those who care about the competitiveness of the U.S. chemical industry might do well to take heed: If U.S. firms lag behind in moving toward green chemistry, given the long period for amortization of chemical plant and equipment, they may lose market share and endanger profitability during the catch-up phase.

Another general consideration bearing on the legislation can be put in the form of a question: Why is there no explicit research on ethical, legal, and social implications (ELSI) of the $500 billion-dollar chemical industry and its associated research infrastructure in universities and elsewhere? There have been set-asides or other ELSI initiatives in connection with nanotechnology, climate change research, and other recent technological inquiries. But not for chemistry, chemical engineering, and the chemical industry. Perhaps it could be said that there is plenty of environmental research already underway, even if not directly connected with chemicals? Just so. However, "chemophobia," as some industry insiders and chemists refer to the public's distrust for chemicals, grew to significant proportions in the late 20th century partly because most people feel excluded from chemical deliberations and choices. This may be a questionable perception, in that consumers do participate in choosing final products. We *feel* excluded, and we do not trust, and we do not understand—and somewhere in that triumvirate is a nontrivial problem concerning the relations of citizens with the chemical industry and the chemical science community. The green chemistry deliberations bring up the possibility of tackling the relationship between chemistry and society in a creative way by focusing on the social components explicitly.

Finally, as Committee Members are aware, the amount of funding being proposed in the pending legislation is small compared with the magnitude of the problem—and the magnitude of the opportunity. Of course, there already are funds being expended, as the other witnesses have pointed out; and, of course incremental funds are a fine idea. So I do not really quarrel with the idea of adding to Green Chemistry R&D within the limits of what will be considered fiscally prudent. Still, looking toward the longer term, it is worth noting that although no one knows the exact number, there are some ten thousand toxic chemicals that may need to be replaced. Taxpayers this year are spending approximately one hundred times as much on nanoscience and nanotechnology research than will be spent under the new Green Chemistry legislation, despite the fact that, in my opinion, Green Chemistry is a more important problem and a more important opportunity. Some observers would go so far as to characterize the nanotechnology juggernaut as a set of techniques in search of a serious issue worthy of taxpayers' concern. I would not go that far. In the case of brown chemistry, however, we have a known problem of proportions far larger than the expenditures now being contemplated.

I turn now to some more specific ideas concerning barriers to the greening of chemicals, and prospects for circumventing or lowering some of those barriers.

Three Categories of Green Chemistry

Chemists divide their world into many technically interesting and important categories, such as solid state, lipid, and carbohydrate chemistry; for our purposes, however, there are just three main commonsensical categories of interest:

1. Green chemical techniques and products that industry may voluntarily utilize because there are no added costs, and sometimes even cost savings;
2. Well understood chemical processes and products that industry probably will not voluntarily utilize, because they are more expensive than current practices; and
3. Potential green chemistry techniques and products that are not yet known or understood.

The goals of public policy should be:

1a. To craft chemical education to make sure that chemists and chemical engineers have the knowledge and skills to make good use of available GC techniques that are already affordable in category one;

2a. To encourage industry to utilize some of the "too-expensive" GC in category two—where a changeover would help solve significant problems created by present chemical technologies; and

3a. To invest in R&D within category three, in order to expand the repertoire of green chemical techniques and products.

Green Chemistry Education Policy

One of the most disturbing things I've observed in my research is how slowly the educational institutions are changing over to Green Chemistry. Not atypical is the situation at one technological university not far from here, where the GC curriculum consists of a single, one-credit course, team taught as a free-standing elective without any connection to the mainstream curriculum. When I asked a chemistry chairperson at a different university about some elementary steps his department could take, he replied, "We do not have room in the curriculum." At another university, the chairperson tried to lead but his faculty refused to follow, saying "That's not the way it's done at Harvard or Chicago." One indicator of the situation, as pointed out by a leader of the Green Chemistry movement, Chemistry Professor John Warner of the University of Massachusetts: About half of U.S. chemistry departments still require Ph.D. students to pass a qualifying exam in a foreign language, but not one requires equivalent proficiency in toxicology.

Now, I acknowledge that meddling in university curricula is a dicey proposition; not trying to improve the situation seems irresponsible, however. What might legitimately be done? One thing we know is that hardly any university departments turn down funding. I expect that Members of this committee would be taken very seriously were some of you to approach the Ford Foundation or other major independent funding sources regarding a Green Chemistry education initiative, perhaps jointly with the National Science Foundation, the American Chemical Council, and other sources? Adding courses in ethics to chemistry and chemical engineering curricula might be the direction to head: One of the leading Green Chemists, Professor

Terry Collins at Carnegie Mellon, has added a significant ethics component to the curriculum there, and advocates that it be added elsewhere.

A parallel tack: Most universities depend on periodic renewals of their accreditation to certify to parents and others that the organization is recognized as offering an appropriate educational environment. At present, the accrediting organizations such as Middle States are not paying attention to whether universities continue to train chemists and chemical engineers in the older approaches or are training students in benign-by-design chemistry. The accrediting agencies should be paying attention, of course, and although I have not studied the matter I am confident that there is a way to encourage them to do so.

A third glaring weakness in the training of chemists is that they do not have to pass through professional licensing, and even chemical engineers can be exempt from it if they work in industry. Those who do sign up for the professional licensing exam administered by the American Institute of Chemical Engineers. I was unable to secure cooperation of the AIChE in my attempts to study the test or the processes behind it, so my information is less complete than I would like. But study guides for the test have changed very little in the past decade, continue to give far more attention to economics than to environmental issues, and evince zero appreciation of the spirit or letter of green chemistry. This appears to be true partly because the AIChE licensing process relies on retired engineers who volunteer their time, rather than on forefront chemical engineering researchers. The Science Committee obviously does not control professional licensing, but chemistry-in-application involves not high-profile researchers but rather ordinary chemical engineers. If they are to function, in effect, as society's delegates in the chemical plants, we need some way to persuade and incentivize them toward greener chemicals.

In short, there are some social barriers to better GC education that are not immediately apparent, and that may not yield readily to research grants or even graduate fellowships. It would be worth a patient inquiry into the matter by those with relevant expertise and access, perhaps as part of the report requested by the pending legislation.

Category 2: GC Affordability and Uptake for Industry

Some of the most knowledgeable advocates for GC speak as if the transition process might be pretty much automatic: Develop the knowledge, and industry will utilize it. I am a bit skeptical of that, as I expect you are. There already is a repertoire of GC knowledge that is ready, but is not being used; and knowledge of that sort is certain to increase as chemical researchers push beyond present understandings of the GC universe.

One example is a water-soluble, biodegradable polymer that the Rohm & Haas Chemical Company developed for use as a brightening agent in laundry detergent. Despite seven years of effort and proven results, the industry continues to use the old non-biodegradable brightener, because the new one would cost about twice as much per ton. When I asked how that would translate at the consumer level, the chemical executive replied, “About one penny”—raising the price of a bottle of detergent from $4.00 to $4.01. For Procter and Gamble, however, that might amount to a million dollars a year if they have to absorb the price increase (which they would not, if every company were required to use the new method).

Technology-forcing statutes of the sort used to reduce air pollution probably are the way to tackle issues of this sort, along with tradable pollution permits, scalable excise taxes, and tax credits; but I realize that such matters are outside the jurisdiction of the Committee on Science. I just want to let you know some of the economic and other barriers I perceive to chemical greening, so that, over time, you can do whatever seems feasible within your domain.

For example, recognizing the barriers to industry participation, the Committee already has taken the laudable step of including chemical engineering research in the pending bill. Still, given the relatively higher status of chemistry, it seems to me likely that chemists will garner the lion's share of the funding. That's fine, if long-term, basic research is really what we want to stimulate. I wonder, though, if more nearer-term engineering efforts might be designed to help move category two knowledge into category one, so that the odds of it being adopted by industry would go way up. This would involve reworking known chemical processes to be greener with the lowest possible incremental costs. Because down time is such a no-no in the industry, for example, any ways of minimizing it translate pretty directly to the bottom line. Engineering researchers may be able to figure out how to minimize disruption of existing chemical production plants, equipment, and processes. Some of the EPA and NSF programs already are doing this, I acknowledge, but they are mainly directed at solvent replacement rather than more complex matters.

I know that many people are reluctant to "pay industry" for doing things "it should do on its own," however I would urge that in setting up the GC research efforts under this bill that your committee establish relatively permissive guidelines. Some of the people who are best positioned to move GC knowledge from category two into category one are those with closest ties to the industry. If they chose to participate in R&D under this bill, I for one would be thrilled rather than dismayed. The draft of the bill I initially read seemed to be heading more in the direction I would favor than the latest draft, which has removed the term "commercial application" in quite a few places. I realize that the matter is a thorny one involving jurisdictional issues, and that the boundary between industry-funded and government-funded endeavors has implications for many aspects of the federal budget. Nevertheless, I recommend that you consider tilting toward greater support for industrial R&D than might normally be appropriate for federal funding of applied research.

The education (or mis-education) of chemists and chemical engineers plays a role in this category also: Not many of our recent graduates are prepared to figure out technically and economically feasible alternatives to the chemical status quo. Just as importantly, they are not operating within a Green Chemistry mind set, and hence are not likely probe very intensively to create new ways of working with chemicals. Note that this way of thinking about chemical greening means that accountants, managers, and attorneys also get drawn into analysis of corporate choices regarding chemical products and processes—implying that, at least in principle, one should be thinking about the education and ongoing training of persons holding such roles. It makes sense initially to suppose that it all comes down to formulas and other relatively straightforward analysis; in fact, it is the culture and psychology of the relevant disciplines and businesses that is as much at issue. None of us well understands how to go about intervening in such complex social phenomena, of course, so my point is merely that we need to be acting so as to turn out much larger numbers of greener chemists, chemical engineers, and others as a way of seeding the industry. In the interim, a great many opportunities for changing chemical pathways, processes, and products may be missed by those operating under the old governing mentality green chemicals are technically impossible or unacceptably expensive.

Category Three: Funding Forefront Green Chemistry Research

I actually have the least to say about this category, even though it probably is the one that comes to mind most readily when one thinks about stimulating R&D in an emerging field. Certainly it is easy to catalyze more Green Chemistry; if you provide the funds, researchers will indeed create justifications for obtaining the money.

Green chemistry is a bit like the Nixon "War on Cancer" or the current holy grail, nanotechnology: Many existing chemistry projects can be tweaked so as to qualify for the new funding. That's not bad, in a way; however, if what one really wants is to catalyze breakthroughs, I'm not sure we know right now how to design a program to achieve that. There's usually something to be said for learning by doing, and one can interpret in that way the three years of funding that would be authorized via the proposed legislation. I do not object to that exactly, but I have seen NSF dispense sums greater than I considered warranted—as in the current round of funding for nanotechnology education proposals I just reviewed last month. Hence, I wonder if there might be a way to at least get a prioritized research agenda at the end of the three years as part of the report to Congress required by the proposed bill.

Further Study of Social Barriers and Prospects

The general provisions for further study in the proposed bill make good sense to me. However, either as part of the bill itself or during its implementation, I would like to see some fine-tuning along the following lines.

First, as suggested earlier in the discussion of ethical/legal/social implications, social science and policy are not ruled out by your proposed wording, but neither are they made as central as the situation may justify. Of course there are important scientific and engineering issues that need to be studied; but much of what stands in the way of chemical greening is social and economic in nature.

That said, I am no fan of the ELSI set aside as part of climate change research, because too much of the money went for relatively trivial investigations. I have to admit, however, that a three percent or five percent set aside does draw the attention of social scientists, historians, and environmental philosophers, and we need some way of getting more of them to attend to the brown/green chemistry problem/potential. It is odd to have a problem and opportunity of the magnitude of Green Chemistry with so little systematic social analysis available, and I would like to see this committee catalyze enough study that when you reconvene for a renewal hearing on this legislation, a lot more social scientists knows something about the subject.

Second, the state of policy thinking on the subject is rudimentary. To my knowledge, there literally is no one who has systematically studied the matter, and no organization equivalent to the former Office of Technology Assessment has drawn in the relevant stakeholders for sustained discussions. Foundations are not funding or studying the problem in the way that the Heritage Foundation, Brookings, and American Enterprise study so many important matters of public policy. Environmental economists are applying their increasingly refined skills to many environmental issues, but not to brown/green chemistry.

Third, and closely related, the problem of brown chemistry is only about ten percent a matter of shortages in supply of technical knowledge—and about 90 percent lack of demand for an alternative to brown chemistry. This committee's jurisdiction obviously pertains to the improvement of science and technical knowledge, not to regulation of the chemical industry. However, this committee may have an indispensable role to play in catalyzing interest by other relevant committees, ones with more regulatory authority over the subject of chemicals. It is of course a dicey matter of how to handle such intra-congressional matters, and I have no wisdom to offer superior to the tacit knowledge you have acquired.

I would urge you not to underestimate the bully pulpit role, however. We associate it with the presidency, especially as popularized by the first Roosevelt; yet most governance is partly a matter of persuasion, and persuasion is largely about good reasons when monetary or other inducement has little bearing, as in intra-congressional life. How might this committee use its staff, use its connections in the relevant industries, use its Members' connections with other committees, and use whatever one-on-one connections there may be with other relevant legislators, industry executives, and executive branch personnel? Such matters rarely are brought up directly in hearings, of course, and yet they occur daily in governmental life. I wonder if there isn't a way to make enrollment of other committees in an overall push for greener chemistry a higher priority?

One example of the kind of policy proposal that would galvanize industry demand for Green Chemistry would be a revenue-neutral tax and subsidy program. Place an excise tax on sales of some of the most suspect categories of existing chemicals, perhaps scaled by industry itself based on estimated risks, and give the funds back to chemical companies as tax credits for innovations in benign chemicals. In effect, the innovative companies would be paid by the laggards. Inasmuch as the largest companies in the industry tend to have the best R&D staffs, and hence are most capable of using technological leadership for competitive advantage, a side effect of the policy probably would be to accentuate the comparative advantage of the most dynamic companies. Among other results, this might better position them for international competition if a transnational phase out of chlorinated hydrocarbons should eventuate.

Finally, it seems to me that the Green Chemistry case raises questions about how public-interest science gets done in the U.S. We proceed as if it were a nonpartisan search for truth, when we all know that ideology, careerism, narrow-mindedness, and habitual thinking are common in science as in other human endeavors. As Michael Crichton expressed the point,

> Just as we have established a tradition of double-blinded research to determine drug efficacy, we must institute double-blinded research in other policy areas as well. Certainly the increased use of computer models, such as GCMs (global climate models), cries out for the separation of those who make the models from those who verify them. The fact is that the present structure of science is entrepreneurial, with individual investigative teams vying for funding from organizations that all too often have a clear stake in the outcome of the research—or appear to, which may be just as bad. This is not healthy for science.
>
> Sooner or later, we must form an independent research institute. . .funded by industry, by government, and by private philanthropy, both individuals and trusts. The money must be pooled, so that investigators do not know who is paying them. The institute must fund more than one team to do research in a particular area, and the verification of results will be a foregone requirement: teams will know their results will be checked by other groups. In many cases, those who decide how to gather the data will not gather it, and those who gather the data will not analyze it. (Crichton 2003).

I find his expression of the idea a bit formulaic, but the core insight has merit. We are in the state we are, trapped in Brown Chemistry, partly because chemists and chemical engineers worked first of all for industry, secondly for themselves and their organizations, and only thirdly for the public. They operated as insiders, not with bad intent but with bad effect, and the arrangement made perfect sense, in a way, considering who was paying. There is a sense in which 20th century chemistry and chemical engineering did not go through sufficiently rigorous "social purposes review" with respect to basic considerations about brown versus green design of chemicals. If Congress and the citizenry want a different sort of chemistry, and a different sort of public-regarding science more generally, it might make sense to face up squarely to the fact that genuine accountability may require more sophisticated arrangements than we now have.

Conclusion

In recent interviews, Jeff Howard asked a half dozen of the world's leading Green Chemists about impediments to chemical greening. By a wide margin, they said that "economic inertia" was the most significant barrier and "professional inertia" came second. Scientific uncertainty and other technical matters were rated as important but lesser barriers. In other words, social factors are more important barriers than purely technical ones.

Although I strongly support the legislation pending before this committee, therefore, I recommend thinking of it as one step in a long process. For the future, I recommend that the Committee consider ways to:

- Increase funding (including tax credits) well beyond what is presently feasible;
- Look into some of the mundane aspects of Chemistry and Chemical Engineering education, in order to catalyze curricular change, promote chemical ethics education, revise university accreditation procedures to enhance social responsibility, and improve professional licensing;
- Draw social scientists and ethicists into study of Brown/Green Chemistry;
- Stimulate chemical engineering economics research to prepare the way for industry adoption of Green Chemistry techniques;
- Go outside the established funding agencies and advisory mechanisms for policy analysis bolder than what can make it through the traditional procedures;
- Use the Brown/Green Chemistry case to reconsider how to arrange much more sophisticated public-interest science;
- Envision a long-term process via which this committee plays a leading role in helping humanity re-vision its relations with chemicals.

9

Change of State?

The Greening of Chemistry

E. J. WOODHOUSE

Most contributors to this volume focus on the movement of chemical molecules into communities, into workers and citizens bodies, and into political controversies. My method is the opposite: I will be tracing synthetic organic molecules *backwards* to their origins in order to reexamine the social construction of chemistry and the problems associated with it.[1] Some of the origins are literal, historical ones; but I am even more interested in the assumptions designed into twentieth-century chemicals and thereby built into many environmental conflicts. Is it possible, I ask, that what we now think of as chemistry, chemical products, and governmental regulation of chemicals, and even how we envision possible future chemical states, all are products of a governing mentality that deserves searching reexamination?[2]

This work emanates in part from a tradition of political thought associated with Langdon Winner s idea that technology *is* politics (Winner 1977, 1986). How (some) humans design chemicals and other technologies helps establish an enduring framework for social order (Sclove 1995). This sociotechnical "constitution" of everyday life is nowhere written down, of course, and hence is even more difficult deliberately to discuss and renegotiate than is a written governmental constitution. The question arising is this: Might it be technically feasible to draw up, ratify, and implement a very different and better constitution for a reformed chemical state?

This chapter is a preliminary report of a long-term project assessing the implications of a form of chemistry characterized as "green"—meaning "benign by design" (Anastas and Farris 1994). Inasmuch as probably not one nonchemist in a million understands the profound difference between twentieth-century chemistry and the redesigned approach to chemicals that appears to be feasible in the twenty-first century and thereafter, one purpose of this chapter is simply to explain the technical potentials and help liberate our imaginations. A second purpose is to improve our theoretical understanding of the relationship among chemical expertise, the environment, human bodies, and social organizations including nation-states. The lynchpin of this relationship, in my eyes, is to be found in the social structuring of expertise: a revised understanding of chemistry calls into question fundamental features of the social institutions and practices that train chemists and other experts, that deploy and incentivize them, and that mediate between experts and the rest of us. The analysis thus helps illuminate the overall challenges of reconstructing a wiser, fairer technological civilization.[3]

The first sections of the chapter compare twentieth-century "brown" chemistry with the green chemistry that is a potential alternative, providing easy-to-understand examples of the new approach. I then go on to discuss obstacles to chemical greening and strategies for accelerating it. The final sections discuss some of the theoretical implications of the case.

Brown Versus Green Chemistry[4]

"Organic chemistry textbooks a generation from now will be unrecognizable compared with today s standard texts," predicts one of the progenitors of what is coming to be called "green chemistry."[5] As the name implies, advocates aim to make humanity s approach to chemicals environmentally benign or "sustainable." With little controversy or publicity, in the past few years a new field has begun to emerge that could turn out to mean a profound transformation in the methods, raw materials, byproducts, and end products of chemical synthesis.

An exaggeration that makes the point is to say that twentieth-century chemistry, chemical engineering, and the chemical industry proceeded according to the following "formula":

- Start with a petroleum-based feedstock;
- Dissolve it, and add a reagent;
- React the compounds to produce intermediate chemicals;
- Put these through a long series of additional reactions,
- Which create millions of tons of hazardous waste by-products,
- While yielding megaton quantities of potentially dangerous final products,
- Released into ecosystems without knowledge of long-term effects,
- Without going through gradual scale-up to learn from experience.

Despite the fact that aspects of the above "formula" appear absurd, especially in light of the public concern over chemicals touched off some forty years ago by Rachel Carson, brown chemistry has remained the basis for textbooks and engineering practice alike throughout the twentieth century.[6] Hardly anyone realized that chemists might adopt a very different approach:

- Design each new molecule so as to accelerate both excretion from living organisms and biodegradation in ecosystems;
- Create the chemical from a carbohydrate (sugar/starch/cellulose) or oleic (oily/fatty) feedstock, instead of using petrochemicals;

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- Rely on a catalyst, often biological, in a small-scale process
- That uses no solvents or only benign ones, and requires only a few steps,
- Creating little or no hazardous waste by-products,
- Yielding small quantities of the new chemical for exhaustive toxicology and other testing,
- Followed by very gradual scale-up and learning by doing.

Experimentation with aspects of this second formula has been gradually developing within the chemical research community and even within the chemical industry (Poliakoff et al. 2002). Going under the rubric of green or sustainable chemistry, the organizational heart of the enterprise has been located in a small program in the Pollution Prevention and Toxics branch of the U.S. Environmental Protection Agency. The program there focuses not on Superfund cleanup or other correction of problems already existing, and not on containing future exposures by cleaning up wastewater or scrubbing smoke stacks. Instead, the focus is on prevention of problems before they occur—by redesigning chemical production processes and products at the molecular level to make them radically less dangerous.

Among the progenitors of green chemistry was Stanford chemistry professor Barry Trost, who first proposed the concept of "atom economy" in 1973. Rather than judging a chemical process successful if it produces usable product at a satisfactory cost, Trost argued that those responsible for synthesizing chemicals should aim for elegant efficiency, for using the highest possible percentage of input atoms in the usable output, ideally leaving zero waste (Trost 1991). This seemed a utopian concept when first proposed, but an increasing number of bio-catalytic and other chemical processes now are being proposed that approximate exactly such an outcome.

The brown chemistry formula predominated partly because chemistry did not start out as sophisticated as it gradually has become. Numerous other factors contributed. For example, the chlorinated compounds that have caused so much trouble (e.g., DDT, PCBs) gained impetus from chemical executives desire to find a use for the excess chlorine created as a by-product of another basic chemical process (Thornton 2000). Then the exigencies of World War I put a premium on finding quick, effective ways to accomplish certain ends, and the resulting means carried over into civilian life via sunk capital, technological momentum, market niches, and habits of professional thought (Travis 1993; Mauskopf 1993; Nye 1993). A not very esoteric example was the cellupaper developed by Kimberly-Clark for bandages (as a substitute for cotton that was scarce during the war), subsequently transmogrified into Kotex sanitary napkins and Kleenex (Vostral 2000).

From World War II came numerous "breakthroughs" including DDT, used by soldiers against body lice and subsequently applied to killing agricultural pests; now banned in most affluent countries, production and use in megaton quantities continues in poorer nations. When petroleum and natural gas feedstocks for chemicals became cheap (and chemically easy), research into lipid- and carbohydrate-based chemistry (from plants) all but disappeared for much of the twentieth century.[7] Additional historical causes for the focus on brown chemistry could be added, but the general point is apparent: Various context-dependent factors led chemists, chemical engineers, and users of chemicals to adopt affordable, doable methods without much inquiry into long-term collective costs. Hence, there never was an across-the-board and deliberate effort to survey chemical knowledge and try to figure out the "best" ways of constructing synthetic molecules. This sort of historically contingent and socially problematic method of choosing among possible technological trajectories is hardly unique to chemicals, of course; for example, there was no significant effort to survey many possible types of nuclear reactors in order to find ones especially suited for civilian use (Morone and Woodhouse 1989).

For the future, however, might chemists and chemical engineers belatedly turn toward more benign approaches to create a greener, if still synthetic, planet? It is not clear exactly how far the idea can be carried into practice, but it appears that the second chemical scenario sketched above may potentially be within the capacities of a revamped chemistry and chemical engineering (Anastas and Warner 1998; Poliakoff et al. 2002).

Examples of Green Chemistry

Examples of recent work qualifying as green chemistry are highlighted by the "Presidential Green Chemistry Challenge Awards" given annually since 1996 by the U.S. Environmental Protection Agency.[8] Included are awards for design of new chemicals that are inherently less dangerous, for creation of safer methods of synthesizing existing chemicals, and for safer solvents. It was the so-called "Reinventing Government" initiative of the Clinton-Gore Administration that created the award competition as part of an effort to reconstruct the state to be less adversarial toward the business sector (Gore 1996; Osborne and Pastrik 1997; U.S. Congress 2001).

The first Alternative Synthetic Pathways Award went to the Monsanto Company for a new technique for manufacturing Roundup™ herbicide in a less dangerous way.[9] Roundup™ is among the less nasty herbicides, and sometimes is described by its advocates as "environmentally friendly." As the award citation put it, in the new process:

> The raw materials have low volatility and are less toxic . . . (and) the dehydrogenation process is endothermic and therefore does not present danger of runaway. Moreover, this "zero-waste" route to DSIDA produces a product stream that, after filtration of catalyst, is of such high quality that no purification or waste cut is necessary. . . . The new tech-

> nology represents a major breakthrough . . . because it avoids the use of cyanide and formaldehyde, is safer to operate, produces higher overall yield, and has fewer process steps. (EPA 1996, 2)

The key to the innovation was a new catalysis technology, potentially "applicable to the preparation of many other agricultural, commodity, specialty, and pharmaceutical chemicals" (EPA 1996, 2).

Another award went to the manufacturers of ibuprofen, the well-known painkiller sold as Advil™ and Motrin™. Synthesizing ibuprofen previously required massive quantities of solvents and achieved only 40 percent efficiency (which means 60 percent waste products), whereas the new process achieves nearly 99 percent efficiency. It "revolutionized bulk pharmaceutical manufacturing . . . (by) provid(ing) an elegant solution to a prevalent problem: how to avoid the large quantities of solvents and wastes associated with the traditional stoichiometric use of auxiliary chemicals when effecting chemical conversions" (EPA 1998, 13).

Dow Chemical won an award for using carbon dioxide as the blowing agent for manufacture of polystyrene foam sheet packaging material. The market for such material had grown to 700 million pounds in the U.S. alone by 1995, principally for egg cartons and fast food containers. The Dow technology allowed elimination of 3.5 million pounds of chlorofluorocarbon blowing agents per year, chemicals that contributed to ozone depletion, global warming, and ground level smog. The CO_2 in the Dow process is derived from existing sources such as ammonia plants and natural gas wells, therefore making no net contribution to climate change.

The Rohm and Haas chemical company developed an improved "antifouling" compound to control unwanted growth of barnacles and other marine organisms on ship hulls. The main compounds used in recent decades to poison would-be fouling organisms have been organotins, which persist in the marine environment and increase shell thickness in shellfish, decrease reproductive viability, and cause other environmental problems. The company s Sea-Nine™ antifoulant biodegrades far more rapidly than previous compounds—with a half-life in sediment measured in hours (compared with six to nine months for the tin compounds). Sea-Nine™ does not bioaccumulate, whereas tin can reach concentrations in marine organisms as high as ten thousand times its original concentration in the paint.

What Chemical State do Visionaries Anticipate?

What do advocates of green chemistry envision, and what are some examples of research and development forefronts? A "2020 Plan" proposed at a University of Massachusetts Workshop on the Role of Polymer Research in Green Chemistry and Engineering has predicted that within two decades it should be possible to:

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- Replace all solvents and acid-based catalysts that have adverse environmental effects with solids, water-based replacements, or other "green alternatives";
- Eliminate nearly 100 percent of emissions in polymer manufacturing and processing, and reduce by more than 50 percent the quantity of plastics placed in landfills;
- Increase energy efficiency by 40 percent or more in the manufacture of polymers;
- Achieve a 30–40 percent reduction in waste (energy emissions, water, and raw materials).

These goals would be approached via "research on alternative manufacturing techniques, solventless processes, new coatings and films, and green separation techniques." Rather than interfering with chemical innovation—not something everyone would fear, but presumably of great concern to industry executives—the workshop participants estimated that the greener processes actually would reduce by 50 percent the development time to produce new polymers, partly by simplifying manufacturing requirements and partly by reducing environmental compliance transactions (2020 Workshop 1998).

One hears pretty much the same sort of expectation from a small but growing number of those at the forefront of chemical research and development. It is reminiscent of what occurred in the field of energy analysis when Amory Lovins estimates of conservation potentials from what he termed "soft paths" were pooh-poohed by early reviewers but quickly proved sensible (Lovins 1977). Likewise, what would have seemed like chemical never-never land a few years ago now looks increasingly like a safe bet. Emblematic of the shift is the simple fact that whereas chemists once washed their hands in benzene, "Today toxicology is very much a part of the way people do business."

Painter Design and Engineering, Incorporated, advertises that its product is "highly effective, economical and leaves no toxic waste" (Painter Design 2002). Florida Chemical uses terpenes derived from citrus oils to replace petrochemical feedstocks, allowing company executives to claim that E-Z-Mulse™ "is biodegradable and does NOT contain suspect nonyl phenol found in other emulsifiers" (Florida Chemical 2002). Such eco-marketing so far seems to be more common in advertising intended for business purchasers than for ordinary consumers, perhaps because the former, on average, are more informed and more highly motivated. This is true in part because of liability issues including workmen s compensation, unionized grievance procedures, and other workplace health and safety advocacy and negotiation. With the exception of certain firms and with the partial exception of some northern European nations, workers bodies often are not taken seriously enough by management to make heavy investments or go to unusual lengths in rearranging production; but when a technological breakthrough allows a relatively low-cost change with minimal hassle, managers are reasonably quick to take advantage of it.

This phenomenon has long been at work in more conventional aspects of the chemical industry. In addition to pressure from workers and from government regulators, chemical company executives found that in many instances they could actually save money over the long run by reducing chemical releases because of money saved on raw materials and in disposal of hazardous wastes. Among large Italian chemical firms, for example, between 1989 and 1997 air emissions dropped by 54 percent for sulfur dioxide, 72 percent for particles, 82 percent for volatile organic compounds, and 92 percent for heavy metals. Wastewater effluents likewise declined, but not quite as substantially (Giuiuzza 1998). Smaller firms have not cleaned up their production processes to nearly the same degree, industry spokespersons say, largely because they lack the expertise and financial resources to do so.

What do these and other changes presage for chemicals in coming decades? According to one advocate, Cal Tech professor Francis Arnold, "The future is limited only by our imaginations."

Obstacles to Chemical Greening

How rapidly the change of state can proceed obviously depends in part on whether the optimistic projections prove technically feasible, and, as importantly, on industry executives perceptions concerning economic feasibility. Movement toward more benign chemicals also will depend on the extent to which government officials put pressure on industry; this will be shaped in part by public interest in the subject, which, in turn, will depend largely on media coverage and on the proselytizing activities of environmental interest groups.

At present, the technical potentials are changing much faster than the social comprehension and response. Even in Europe, most regulatory activity focuses on correction or containment of environmental problems already existing. An exception is the announced plan of the Swedish Chemicals Inspectorate to phase out a dozen especially toxic chemicals, and has some 250 on an "observation" list that pretty clearly are candidates for being banned. Other European nations are moving in that same direction. But even this move is timid compared with the bold possibilities foreseen by a handful of green chemistry visionaries, such as former Greenpeace staff member turned biologist Joe Thornton, who has constructed a detailed argument suggesting that it is technically and economically feasible to phase out virtually all chlorinated chemicals (Thornton 2000).

Systematic inquiry and debate about such a possibility is slowed partly by the way that mass media handle environmental stories. Coverage on television and in newspapers may not be entirely commensurate with the magnitude and scope of the problems, but a greater obstacle is that the focus normally is on symptoms rather than on the underlying problems. Endangered species and habitat loss, spills of hazardous chemicals, toxic torts and their victims, and ordinary air and water pollution capture most of the attention (Allan et al. 2000; Hansen 1993). In the instances where a story deals not with problems but with potentials for solving problems, the emphasis usually is on cleaner emissions, with no consideration of possibilities for more fundamental redesign. In a sense, therefore, media coverage of environmental issues may actually tend to take attention away from fundamental issues concerning design of benign chemicals.

Environmental groups likewise generally remain locked into the governing mentality of the 1970s and 1980s: on the one hand, chemicals are inherently villainous; on the other hand, it is politically and economically infeasible to forego the chemicals' benefits. The only viable option, therefore, is treating wastewater, scrubbing smoke stacks, and otherwise trying to keep chemicals away from living organisms. Given the ubiquity of chemicals in contemporary society, the sequestration approach rather quickly runs into difficult obstacles.

Green chemistry advocates accept pollution cleanup and sequestration methods as part of the story, of course, but they entertain a far more radical option: preventing problems before they occur by (re)designing chemicals and chemical production processes so as to come as close as possible to inherently benign. By recognizing that synthetic organic chemistry is highly malleable and that social goals potentially can drive the rearrangement of molecules to serve public purposes, a new governing mentality becomes available that could lead to a reconstructed chemical state.

That there has been some movement toward institutionalizing this social movement within chemistry is indicated by the fact that there now is an annual Gordon Conference on Green Chemistry.[10] The U.S. National Academy of Sciences serves as the venue for a different annual conference covering green chemical engineering as well as green chemistry. The Organization for Economic Cooperation and Development's Chemical Risk Management Program also has began to tackle the subject. The International Union for Pure and Applied Chemistry focused on green chemistry at its 2001 conference in Brisbane, as did that organization's CHEMRAWN Committee (Chemical Research Applied to World Needs) at an international conference that same year in Boulder. Although scientists and technologists predominate at these conferences, there is some outreach toward interest groups, government officials, journalists, and other nonexperts.

The Green Chemistry Institute cosponsors numerous conferences, and now has more than a dozen affiliate organizations throughout the world (Green Chemistry Institute 2002). The main Chinese technological university, possibly leapfrogging western universities with greater institutional momentum and fixed capital, has recently opened a new building for a green chemistry initiative. A committee of the American Chemical Society is at work attempting to revise chemistry textbooks and curricula. *Chemical and Engineering News* has begun to feature articles on the subject, and the Royal Society of Chemistry has launched the journal *Green Chemistry*.

These many signs of life notwithstanding, as in most social institutions there is in chemistry, chemical engineering, and the chemical industry considerable cognitive, institutional, and other momentum standing in the way of the transformation. This is about as true in universities as it is in industry and government. When a prestigious Australian chemistry chair proposed to his department "a half dozen" good reasons to switch from their outmoded division among physical, organic, and inorganic chemistry to an organizational form more in keeping with contemporary practice, he "provoked outrage" and the best he could obtain was a study committee. Asked to come up with any good reason for maintaining the current substructure of the department, the committee majority responded, "That s the way it s done at Harvard and Chicago." The scientific state of academic chemistry, one might say, is conditioned by the politics of the academic estate, by the status hierarchies, sunk human capital, and even the laboratory equipment designed for earlier trajectories of chemical research and teaching (Bell 1992; Croissant and Restivo 2001; Greenberg 2001).

Additional Examples

One of the hot areas in green chemistry is that of trying to move toward solventless processes, or at least to synthesis pathways and techniques that use less dangerous solvents such as ketone and ether. A promising line of investigation concerns the use of supercritical fluids, particularly carbon dioxide (Kiran et al. 2000). The basics of scCO_2 have been understood for about a century, yet until recently there were only a handful of chemical processes utilizing the technique, of which the best known is that of decaffeinating coffee (Williams and Clifford 2000).

Opinions differ on why this has been so. Some point to the capital expense of building equipment to operate at the temperatures and pressures necessary for achieving supercriticality. This seems a bit questionable, in that the pressures involved are only about 4000 pounds per square inch, and the temperatures are within the range often found in industrial practice. Other observers nominate maintenance difficulties and costs as the culprit. Still others argue that safety is harder to assure when dealing with pressurized systems. No doubt there is validity in these claims, but given the life cycle costs and environmental-social costs of many petroleum-based solvents, it seems pretty clear that a huge number of chemists in and out of industry have for decades not been paying appropriate attention to the potential advantages of scCO_2 and other supercritical fluids (SCFs).

A chemistry professor working on SCFs in the UK suggests that the explanation rests partly with the faddish way scientists sometimes approach new techniques. There have been recurrent cycles, he says, in attention to SCF potentials: first the potential is oversold as enthusiasts propose and try out fancy schemes far beyond the existing state of knowledge; then, when these fail, participants and funding agencies make the interpretation that SCF has not worked out, and attention turns to some other hot topic. An obvious alternative would be patient, steady exploration of whatever fundamental questions remain, coupled with modest chemical and other engineering innovations designed to apply relatively simple SCF technology in relatively simple manufacturing and other processes. But such steady attention to a high-priority social task would require agenda-setting processes and linkages between political institutions and research institutions better than those now prevailing (Cozzens and Woodhouse 1995; Woodhouse et al. 2002).

A more modest, successful approach is illustrated by the work of Materials Technology Limited (MTL) of Reno, Nevada, which in partnership with the Navaho Nation operates a facility next to the Four Corners Power Plant in the southwestern United States. As the primary raw materials for manufacturing a line of new products, MTL is using waste fly ash that formerly had to be hauled away, CO_2 from the stacks that formerly was released as a greenhouse gas contribution, and thermal waste heat. Thanks to supercritical technology that turns the CO_2 into a solvent, the company is able to achieve molecular bonding that gives the products improved functionality coupled with lighter weight than competing materials (Jones 1998; cf. Rubin and Tyler 1998).

The firm s founder was unable to get any assistance from the federal government in this start-up venture because "it did not fit into existing environmental programs; and venture capital firms were not interested because the process was deemed too risky." Ironically, the main innovation required in the MTL case was not technoscientific but social: the entrepreneur *set out* to create a new business that would sequester carbon dioxide while utilizing waste products from an existing, but initially unidentified business. He had no specialized training in SCFs, and merely uncovered their potential while doing research to figure out how to make something out of the materials available. Other green chemistry practitioners report being turned down or downgraded in status because their work seems "too applied" or otherwise not sexy enough.

Staff in Congress and at the Office of Management and Budget in Washington have known too little about the emerging potentials to take the lead in educating their superiors about the ways green chemistry may lead to modifying traditional approaches to environmental regulation. Top administrators at EPA tend not to be very knowledgeable about cutting edge science, perhaps any science, and the dozen or so EPA staffers most directly working on green chemistry and engineering have been committed to voluntary cooperation with industry, as are most of the chemical researchers I interviewed (and, of course, industry executives).

It is true that harmonious relations have been preserved with industry and that the green chemistry (GC) movement appears to be gaining momentum, if number of conferences and growth in number of interested researchers is an accurate gauge. But with the exception of Rohm and Haas, industry participation at GC conferences has been lackluster, and I have not seen evidence of a massive shift in industry practices. This impression is confirmed at least in part by minimal activity on the subject at the American Chemistry Council (formerly Chemical Manufacturers Association), which has lent its name to several green chemistry conferences, but has not focused real money or attention on the subject as of this writing. In mid 1998, responsibility for one such conference was assigned to a junior staff member in the Regulatory Affairs Division, which apparently was because those with more seniority "did not know how to fit green chemistry into the organizational structure." The organization's members—the largest players in the chemical industry—generally "do not seem very interested in green chemistry."

A number of European government officials have told me they do not find the North Americans' purely voluntary approach persuasive; nevertheless, as of 2002 European environmental agencies had nudged industry only rather gently toward fundamental redesign of chemicals.

A Few of the Implications

Shifting toward a new chemical state almost certainly would require addressing the political obstacles to a shift in governments' regulatory approaches toward the chemical industry. This probably requires creation and diffusion of a new imaginary, a new vision of how to operate a synthetic planet in ways that do not threaten the health or environmental integrity of the natural planet. Yet, it is far from obvious how the old enunciatory community and its governing mentality can be reformed or revolutionized (Anderson 1983).[11]

This is true partly because of the momentum problem introduced above. Chemistry and chemical engineering majors still do not study much about benign design, and chemistry professors left to their own accords have not changed curricula much in this regard in the past decade. In principle, accrediting agencies could force a more rapid pace of curricular adaptation; in practice, however, organizations such as the Accreditation Board for Engineering and Technology (ABET) uphold tradition more than departing from it (Accreditation Board for Engineering and Technology 1991; American Academy of Environmental Engineers 1999). If professional licensing exams for chemical engineers emphasized environmental considerations (which at least in the U.S. they have not), the curriculum might move in that direction. Or if large sums were available for innovations in benign chemical education, recalcitrant faculties might suddenly find room in the curriculum. But brown chemistry's momentum remains strong as I write (Hughes 1969; Staudenmeier 1985; Hughes 1989).

Thus, one Lawrence Laboratory scientist expressed bitterness that the Department of Energy killed his research project after four years despite the fact that it was on schedule to do exactly what he d promised. He felt "pressured by DOE to obtain industry funding," but found the businesses he thought needed the technology uninterested. And those doing peer review at funding sources such as the National Science Foundation tend to look down on green chemistry proposals as "too applied." "Science politics sometimes are more important than science," a practicing scientist told me during my research, wearing a facial expression suggesting that social scientists would not previously have entertained such a thought. If science inevitably is a human activity that is bound to involve habit, politics, and other controversial judgments, and if the green chemistry case suggests once again that "science is too important to be left to scientists," what would it take to go beyond that clichéd insight?

One direction that seems clear to me is to explore the possibility of bringing to chemical design more of the relatively open, participative, and frank negotiation of democratic politics. Chemical engineering is an inherently political activity, as is all engineering, because it restructures everyday lives of workers, chemical plant neighbors, organisms in the environment impacted by hazardous wastes and plant emissions, and those who come into contact with chemical products (Woodhouse 1998).Arguably, technoscientific research and innovation now exercise greater influence over ordinary people s lives than did government in the centuries when democratic principles first were being applied. If so, is there not ample reason to ask whether and how it would be appropriate to think about democraticizing the technosphere, including that pertaining to toxic-versus-benign chemicals (Mumford 1934; Winner 1977; Sclove 1995).

The case raises interesting and important questions about whether and in what ways more democratic participation in setting scientific agendas arguably could have made positive contributions to shaping chemistry in the late twentieth century. More importantly, it raises questions about where democratic methods might be used in the future to steer science differently and perhaps better (Fuller 2000; Cozzens and Woodhouse 1995). The lessons I tentatively take away from the green chemistry story derive in part from commonplace understandings:

- Very substantial damage to environment, workers, and users of chemicals resulted from the actions of chemists and chemical engineers (in collaboration with others) in the twentieth century;
- Many or most of those technical personnel devoted relatively little attention to investigating, publicizing, or protecting against the risks of the chemical products they helped make available for commerce;
- Nor did most technoscientists seek diligently to find alternative synthesis pathways that would produce fewer waste byproducts of lower hazard;

- Nor did most chemists and chemical engineers seek to develop (or recommend, if already existing) alternative final products that would take the place of chemical products posing risks.

Knowing what we now do about the potential for benign chemicals, one can infer that many environmental and health problems might have been avoided or reduced if scientists and engineers had moved more expeditiously to investigate, develop, and utilize different techniques. What stopped that from happening is partly conjecture at this point, but a few key points are hard to miss, starting with the fact that most chemists and chemical engineers work directly or indirectly for industry, and their careers depend on the continuing goodwill of corporate executives. Both the great successes and the horrible failings of the past century s chemistry can be traced in part to this relationship.

Second, we know that university chemical researchers exercise substantial discretion over their research and teaching, although obviously influenced greatly by other members of their fields. This helps insulate them from undue external influence, except from companies awarding consulting contracts and research grants. The academic freedom also partially insulates them from accountability for those aspects of their work that have impacts outside the university, impacts on the general public and on the biosphere.

Third, we know that the split between scientific and social science/humanities education just about assures that most supposedly educated people will not know much about chemistry (or other sciences). Most of us know next to nothing about reduction, oxidation, methyl groups, ring-opening polymerization, or anything else involved in chemical processes and products. Nor do we know much about biochemistry and the new catalysis-based chemistry coming to the fore. That might be all right, if there were public interest scientists we could count on to represent us competently, with relevant expertise that is relatively independent from established cliques and hierarchies within mainstream chemistry itself. Sierra Club, the Environmental Defense Fund, British Nature, Greenpeace, and other major environmental groups have some scientifically competent staff members, of course, but they are relatively few in number—and disproportionately drawn from biological rather than chemical sciences. The world has nothing approaching the number of public interest scientists that would be needed for competently overseeing the work of experts employed primarily by business (Primack and Von Hippel 1974).

Fourth, partly because of the above, we know that contemporary societies do not have well-designed and fully articulated social institutions for monitoring chemistry and chemical engineering. Nor do most nations have satisfactory institutions for interpreting and deliberating about emerging directions, or for setting priorities in a way that integrates broad public concerns with relevant expertise. In the U.S., for example, the House Science Committee, the appropriations subcommittees, and other relevant committees exercise far more detailed and sophisticated scrutiny than what is available in the British or French parliaments, but Congress nevertheless delegates most decision-making about chemistry and chemical engineering to the National Science Foundation, the National Research Council, and to the university and industry sectors. That seemed like a fine arrangement to most people for most of the past several generations, but the unwanted legacy from brown chemistry raises serious questions about abuse of the authority traditionally delegated to chemical scientists and engineers and their institutions.

Neither social scientists nor other observers of science have offered penetrating, constructive ideas for how to arrange genuine accountability for scientists and scientific institutions. Science fraud and related issues have drawn a fair amount of attention, leading to tighter auditing, institutional review boards, and other procedural safeguards (Wells et al. 2001). But the reformers have not usually focused on substantive research directions, in part because it is widely assumed that only those within a subfield are in a good position to judge which topics most deserve investigation.

Yet the green chemistry case suggests that in some respects insiders can be exactly the wrong ones to control priorities, because they can be wedded to habitual ways of doing things that suit themselves and their benefactors more than they meet the needs of humanity and the ecosystem. The basic insight of pluralist political thought is that increasing the diversity of participants brings to light important considerations that are accidentally or willfully neglected when decision-making is controlled by those with the greatest stake in the outcome (Lindblom and Woodhouse 1993; Dahl 1998). I see insufficient reason to believe that this principle would not apply to scientific institutions and to the negotiations occurring therein.

Another reason for mounting serious inquiry into the possibilities for broader, more open negotiation concerning the design of chemicals is that the pendulum seems to be swinging too far in the direction of "cooperation" with industry in many nations. "Co-optation" has just about the same spelling, and, I fear, in some cases the same meaning. One ought to worry when public official after public official, and academic scientist after academic scientist, speaks of "forming research agendas based on industry needs," "Industry + university = new science and new process," "environmental improvement and economic growth are not in conflict," and so forth. I am sure that negotiation often makes sense; but blindly relying on business executives and their employees to serve public purposes does not fit with some of our most reliable understandings from economics and political science concerning market shortcomings and the privileged position of business (Lindblom 1977, 2001).

Conclusion

Given the inherent malleability of synthetic chemicals and the myriad, partially conflicting public and private purposes to which they can be put, one might have expected high levels of controversy from the outset of the chemical era. Instead, the modern chemical state has generally been characterized by a strange quiescence, by an eerie acceptance (Edelman 1971). This claim seemingly is belied by the intense controversies over Bhopal, Agent Orange, toxic waste at Woburn and Love Canal, Gulf War Syndrome, and other chemical-political events. In light of what we now know about solvent replacement and other aspects of green chemistry, however, it becomes apparent that neither the famous controversies nor the quieter, business-as-usual regulation of chemicals actually have gotten beneath the surface to problematize matters at a molecular level. The struggles normally have concerned how dangerous dioxin is, or how many people have been harmed—in other words, struggles over medical and scientific knowledge about chemistry-as-usual instead of over the chemistry-that-might-be. The question rarely if ever asked, the demand rarely if ever made: redesign chemical activities from scratch to be inherently benign.

Given that the majority of the chemical industry s activities could have been pursued quite differently, in ways radically less prone to create health and environmental risks, it is clear in retrospect that there has been a dreamy, somnambulistic quality to the ways government officials, consumers, workers, and even environmental interest groups have largely accepted whatever chemical engineers and their employers decided to offer by way of chemical synthesis pathways and products (Winner 1977, 1986). If more people had known of the potentials of green chemistry, they would have been in a position to search for counter narratives to those disseminated by industry and by the mainstream chemistry community (Roe 1994). Having not known to question the mentality governing brown chemistry, however, even environmentalists have been trapped into debating chemical activities within the relatively narrow discourse deployed by the dominant community of chemical practice.

Whereas public policy conventionally is conceived as emanating from government, nongovernmental decisions about technology by technologists and their industrial employers in fact have transformed everyday life in ways more profound than anything governments normally do. Innovations in communication, transportation, manufacturing, household, and leisure technologies lead to fundamental changes in the ways people spend their time, money, and attention. "Innovations are similar to legislative acts or political foundings that establish a framework for public order that will endure over many generations" (Winner 1986, 29). And just about everyone—from the crassest spokespersons for the chemicals industry to the most outspoken environmentalist critics—has bought into the brown-chemistry framework, has looked at the chemical state via the same impoverished governing mentality. If this is to change across the board, ways will have to be found for expert communities not to lock into overly narrow ways of inquiring and thinking.

Governments were involved, certainly, but chemists and chemical engineers arguably were the primary policy makers in establishing the enunciatory community whose discourse and worldview framed how the rest of us approached our roles as toxic victims, environmental activists, consumers, chemistry students, science journalists, government regulators, and industry executives. The result of the narrow thinking within chemistry and chemical engineering was to help form a "nation," an imagined community, whose shared imaginary was oriented around a single, unduly limited version of chemistry and chemical products (Anderson 1983).

If chemists and other experts are to participate more helpfully in the future in nongovernmental (as well as governmental) policy making, nontrivial revisions in the social relations of expertise would be required (Woodhouse and Nieusma 2001). A new sociotechnical constitution for a new chemical state would need to arrange for:

- Many different interests to negotiate via democratic processes;
- Drawing on much more diverse sources of expertise to understand the potentials and problems;
- So as to design nation-state regulatory policies and other social norms and practices that strongly encourage university science and engineering faculty to give very substantial weight in their teaching, research, consulting, and public commentary to chemical ideas and practices highly protective of environment and health;
- And that evoke from industry only those innovations in the design of new molecules that are biologically benign, or close to it, both in terms of manufacturing processes and in terms of final products;
- Thereby protecting the bodies of workers, consumers exposed to chemical products, and living organisms in the environment.

If every step in this process was violated egregiously by the brown chemistry of the twentieth century, some of the violations surely were due to a nearly inevitable naïveté about chemicals that was nobody s fault. However, many of the violations were due to the studied indifference and even willful neglect that is typical of elites making decisions with inadequate accountability—in this case, chemical executives, their technical employees and contractors, their allies in universities, and government officials pursuing wartime successes and peacetime economic competition.

Inasmuch as the chemical state emerged via a complex sociopolitical process, however, it may be more instructive to use our new appreciation of chemistry s potentials to acknowledge how far humanity has yet to go in designing the social relations within which expertise functions. Citizens ignorance, consumers nonchalance, educators myopia, journalists inadequate training—the list of factors in the overall social construction of contributory negligence is long. It may not be too strong to say that inappropriate chemical expertise and poorly designed intermediary institutions have crippled public understanding of environmental problems and mistargeted nation-state practices concerning chemical innovation and regulation.

Because equivalent problems apply to some degree to every field of expertise, and because experts and their knowledge claims now are implicated in just about every human activity, the overall project of redesigning expertise probably amounts to a partial redesign of human civilization. As important as the design of benign chemicals surely is, therefore, the case of green chemistry could become far more important if it helps put us on the road to the daunting but also inspiring destination of a civilization based more firmly on reasoned inquiry and sensible experimentation, where knowledge is placed in the service of wisdom more than in the service of the ends favored by twentieth-century brown chemistry.

March 17, 2004

The Honorable Sherwood Boehlert
Chairman, Science Committee
2320 Rayburn Office Building
Washington, DC 20515

Dear Congressman Boehlert:

Thank you for the invitation to testify before the Committee on Science of the U.S. House of Representatives on March 17th for the hearing entitled *H.R. 3970, the Green Chemistry Research and Development Act of 2004.* In accordance with the Rules Governing Testimony, this letter serves as formal notice that I received no federal funding directly supporting the subject matter on which I testified, in the current fiscal year or either of the two proceeding fiscal years.

Sincerely,

Edward Woodhouse

DISCUSSION

Chairman BOEHLERT. Thank you, Dr. Woodhouse, and thank you for those suggestions and the excellent testimony. I have got a suggestion for you. You tell a story exceptionally well. I would hope that you would consider doing some thoughtful op-ed pieces, because part of the problem is that the public needs to be educated in this area. And some of the examples you gave are outstanding examples. And some op-ed pieces would, I think, get people's attention. So thank you very much for that testimony.

The Chair will yield the Chair to the author of the legislation, Dr. Gingrey. I have to take leave for a few moments, and he will lead off with the questions, and then he will recognize Ms. Johnson.

Mr. GINGREY. [Presiding.] I thank the Chairman and I thank the witnesses for their testimony.

Let me just start off the questioning, and this actually will be for all five of the panel members. Hopefully, you will want to comment. In what ways do you think that this bill, H.R. 3970, would accelerate adoption of green chemistry in the private sector? And please describe the elements of the bill that you think will have the greatest effect. And we can start with Dr. Bement.

Dr. BEMENT. One program at the National Science Foundation that, I think, has a great potential in that regard is our work in entrepreneurship and innovation—partnerships and innovation that link the private sectors with universities, and especially small start-ups, because this is an area that is evolving very, very rapidly. There is a very broad, rich spectrum of research going on at universities right now that have potential economic, as well as environmental, benefit. And what is needed right now is to compress the lead-time of getting some of these new concepts into the marketplace. And I think that these types of partnership programs would be most useful.

Mr. GINGREY. Dr. Gilman.

Dr. GILMAN. I actually think one of the benefits of funding research, as you have proposed, is the spillover that happens in places of education with doctoral and undergraduates being introduced to the field of research. I think as they find their way into industry, the folks who have an understanding and the knowledge about the use of these approaches, green engineering and green chemistry, make it easier for the private sector to adopt those approaches. So I think that is an indirect benefit of what you are proposing to do with the legislation.

Mr. GINGREY. Dr. Cue.

Dr. CUE. I see three potential benefits to this legislation. First and foremost, I think it brings the Federal Government focus to green chemistry that has been too infrequent in the past. Like many in my generation, I went into science because our national leaders challenged us in the early—late 1950s to respond to the embarrassment of Sputnik. And I believe that a similar challenge to industry and to academics will generate the same response in green chemistry. Specifically, this is going to dramatically, I believe, improve the situation with regard to students going into green chemistry and academia, because more money will be available to have that happen; more universities will have green chemistry programs, and companies like mine will be hiring chemists, who, from day one, know about green chemistry and can practice green chemistry principles.

I also believe this is an opportunity to better integrate government, industry, and academic activities around green chemistry.

Mr. GINGREY. Thank you.

And Mr. Bradfield.

Mr. BRADFIELD. I would say that solid science is absolutely critical to changing some of the economic and professional inertia that Dr. Woodhouse was speaking about before. We absolutely can not go forward without the kind of cooperative projects between the universities and industry that are going to provide that kind of scientific foundation. It also sends a signal to stakeholders that we have a concern in the case, the Federal Government, and the value of that can't be underestimated.

Mr. GINGREY. Thank you.

And Dr. Woodhouse.

Dr. WOODHOUSE. I like the part about expanding the education and training of undergraduate and graduate students. How to achieve that, however, is an interesting question. And one of the possibilities that I would recommend to you is to consider the possibility—whether or not there may be connections that Members of this committee have with Ford Foundation and other groups of that nature so that you could use your symbolic capital in a way that would greatly magnify the funding that you can otherwise provide so that university departments rarely turn down offers of funding. And yet without very substantial offers of that kind, I fear that chemistry and chemical engineering professors will not take the time and effort to retool their curricula. And so I would look for creative ways to leverage that don't cost federal dollars.

Mr. GINGREY. And if I could ask just a real quick follow-up before yielding to the Ranking Member, H.R. 3970 authorizes an interagency research and development program. And do you think that greater federal investment in green chemistry R&D would actually increase adoption of green chemistry by industry? Anyone?

Mr. BRADFIELD. I would say absolutely. One of the things that we find today is we have to cast about—out in the marketplace, in cooperation with university partners, for grants in order to find the way to fund a lot of these things, which are—will underpin the ultimate green chemistry that finds its way into practical applications in industry. These are basic research projects that would have applicability to a wide range of industries, and not necessarily to any particular industry or industry player, such as Shaw Industries. We believe that those are the kinds of things that should be done as a cooperative effort between academia and government and the industry. Anything over and beyond that, we, as individual companies, should be willing to fund and invest in on our own. But it creates a tremendous base of understanding in basic research.

Mr. GINGREY. Thank you.

Dr. WOODHOUSE. I see this as being not solely about formulas and tactics, but about being—regarding hearts and minds, vision, worldview. What is it that humanity ought to be aiming for? And so in that sense, it may be that the particular research that is catalyzed is less significant than the signal that is sent regarding the importance. I believe there will be the beginnings of a trans-national phase-out of many of the most toxic chemicals in the 21st century. We are not ready for that. We can get readier by some of the research that this will catalyze. So I think both the tangible and the intangible matter here a great deal.

Mr. GINGREY. Thank you very much.

And I see my time is expired, so at this point, I will yield to my friend from Tennessee, the Ranking Member, Mr. Gordon, for his question. Thank you.

Mr. GORDON. Thank you.

And this is a question for the panel at large. In addition to the benefits that this bill will provide, what other federal actions could be taken that would accelerate the adoption of green chemistry? We will just start at the—my left and work around.

Dr. BEMENT. Yes. Thank you, Mr. Gordon. As you know, there is plenty of incentive these days to develop as much leverage of available research and development resources as is possible, especially with tight budgets. The opportunities in research, especially in green chemistry, are far greater than the amount of resources. So we have been incentivized for several years in working closely with EPA, with the Department of Energy, and with NIST in trying to get more output, more outcome, for the amount of R&D investment——

Mr. GORDON. Okay, but what additional federal actions could we take? What would you recommend, additional actions beyond this bill that would accelerate the process?

Dr. BEMENT. Quite frankly, I can't really come up with anything highly creative other than——

Mr. GORDON. Okay. That is all right.

Dr. BEMENT.—what is currently being done.

Mr. GORDON. That is fine. Let us just work on down the Committee and see if we do have some creativity here somewhere. Anyone else have any suggestions? Yes, sir.

Dr. CUE. Within the pharmaceutical industry, one of the challenges that we face in applying green chemistry solutions to existing manufacturing processes is if we change the manufacturing process, we almost always change the purity profile of our product. That could require, in many cases, redoing expensive development studies in order to prove to the Food and Drug Administration that our products are safe. And that is an issue that I have no solution to addressing, but clearly, I believe, is something that we need to address, at least in the pharmaceutical industry, as we go forward. How do we act on these new scientific discoveries in a way that allows them to be incorporated without altering the quality of our products?

Mr. GORDON. Yes, sir. Go ahead.

Mr. BRADFIELD. Several things could help, from an industry point of view, and my—and in my view. Certainly tax credits are always welcome in trying to put new investment out there, which may or may not pay off. We take a tremendous risk when we put a couple hundred million dollars into a program for which we may actually get no return whatsoever. In the case of Shaw and EcoWorx™, we got tremendous payback on that product. And the public got good value. Federal purchasing, based on multiple environmental impacts versus single impacts, like recycled content, would be extremely helpful in helping to understand exactly what all of the impacts are of development, not simply a one-dimensional impact.

And then, of course, one of the things that we see happening today is many people are rushing to put standards in place for environmental programs, and yet we don't know enough. We don't have enough good science yet to do anything more than offer those as guidances. And so I think there is rush to judgment, in some ways, to put hard and fast standards in at the federal level. It needs to be mitigated a little bit by that caution of saying, "We may know tomorrow more than we know today. Let us take a slow approach here."

Dr. WOODHOUSE. In the nanotechnology legislation this committee was largely responsible for, you had thoughtful consideration about public participation. And it seems to me that something analogous to that could be beneficial in the green chemistry case. It is not as obvious, since it is a different phenomenon, how to go about it, but the environmental interest groups are not paying the attention to green chemistry that they ought to. Journalists are not paying the attention to green chemistry that they ought to.

Mr. GORDON. But that is not federal action; I am asking——

Dr. WOODHOUSE. I am——

Mr. GORDON. Okay. You will get there.

Dr. WOODHOUSE. Yes. I hope so. The social scientists are not—very few social scientists have been—in history of science, for example, history of 20th century chemistry, is one of the least represented fields. So one of the things I would consider catalyzing is additional social science attention and, more generally, social attention to the phenomenon. And that is something that sometimes funding of the sort that is targeted set aside can assist with. So the ethical, legal, and social implications programs that go with some federal science bills, might be worth considering.

Mr. GORDON. All right. Let me just, finally—let us assume that we have a consumer epiphany here in this country, and they go to the industries involved here and say, "We have just got to have," you know, "green products. We just can't live without them, and we are going to pay you more for them, and so please get them out on the market." So that happens. But what happens so oftentimes then is that it is still going to be more expensive. Third-world countries are going to say, you know, "You have made yours. You can afford to do this. We can't, so we are not going to go forward." So how do we deal with this on an international basis? Anybody have any suggestions?

Mr. BRADFIELD. I think there are a couple of things that work there, Mr. Gordon. The third-world problem is, and it is a thorny one, as you well know as legislators. It has been said that between—we would need between 4 and 4.7 planets the size of the Earth in order for everyone around the globe to enjoy the same level of standard of living that we do here in this country. And you can imagine what a tremendous drain that would be on the resources almost overnight. That would put us in a cataclysmic situation.

What we have to do is be willing to share best practices and to transfer technology, in my opinion. We can not afford for other countries to go through the learning curve that we did in a cradle-to-grave economy. We must move in a cradle-to-cradle loop and be willing to share those loops and get those into other economies and get them beyond that paradigm much more quickly.

Mr. GORDON. Thank you.

Thank you, Mr. Chairman.

Mr. GINGREY. Thank you, Mr. Gordon.

And I will now recognize the physicist from Michigan, my good friend, Dr. Ehlers.

Mr. EHLERS. Thank you, Mr. Chairman. It is—I am a physicist only because I had a few explosions in chemistry lab. No, not really. But I have to say, when I was a student, the only green chemistry I saw was the molds growing on some leftover samples that I neglected to get rid of.

I am very delighted with what is happening with green chemistry. And I guess—it seems to me the question here is how can we accelerate the change. What are the factors here?

And let me focus in on just one. I was very surprised to hear from Dr. Woodhouse the—not only that there is very little green chemistry taught, but that there seems to be opposition on the part of chemistry faculties to teaching green chemistry. Perhaps I shouldn't be surprised. That bears out an adage that I always used to say to—or a saying that I propagated to my colleagues when I was a teacher, and that is that professors and teachers are, in a sense, bi-polar: they are the world's most liberal people about other people's affairs and most conservative about their own affairs. And so they are quite willing to change the world, but not willing to change their department or their courses. The—and then I spent my life trying to fight that tendency within myself, and didn't always succeed, so I am not being supercritical. But a question for each of you, other than Dr. Woodhouse, and that is what do you see as the status of green chemistry education in the U.S. today? Are chemistry students graduating with green chemistry skills and knowledge or not?

And specifically for Dr. Cue and Mr. Bradfield, do your companies typically have to train scientists in green chemistry when you hire them, or are you finding students on the market who do have green chemistry skills?

And the final question is: does having green chemistry skills improve their marketability in the job place today?

So we will just go down the line. We will go right to left this time. Mr. Bradfield.

Mr. BRADFIELD. What we find is we hire a tremendous number of scientifically-based professionals: a lot of engineers, both chemical and mechanical, textile engineers, and so forth. We find that they come to us with a certain bias toward doing it the old way. There is definitely some retraining that has to go on in trying to change the way they think about some of the things that we are trying to achieve. I do believe that it is very hard to break down those barriers, but when you get them young and get them trained and indoctrinated into some of the things we want to do, and we find that they respond very quickly.

The biggest single hurdle, and the reason for my existence within the—our organization is simply because I am the guy that says, "We will not take no for an answer." I am the guy who does not believe that it can not be done. When there are—seems to be so much scientific certainty, this says that it can not be done. And so it takes change agents. It takes problem-solvers. It takes people who believe that there is a way, if you only look hard enough. And what we have found is many of those same chemists and engineers, in the end, become believers once you show them that there are, indeed, ways to move forward.

Mr. EHLERS. The irony is that I have always felt that scientists, intrinsically, should be change agents just because that is the nature of science. And it is shocking if students don't see themselves that way.

Dr. Cue.

Dr. CUE. There is a saying that is very popular at Pfizer right now, and that is that "culture eats strategy for breakfast every day of the week." And green chemistry is really a strategy so far, and I think what it needs to be is a cultural change. So I believe it is absolutely true that most chemists, trained in academics, don't get enough exposure to green chemistry, nor do they really understand the difference between green chemistry and traditional chemistry.

There are some very good schools in the United States that train chemists in green chemistry, and the programs on toxicology and environmental chemistry are increasing, but the pace has to increase, and the number of these schools has to increase. And I think industry has to be more active in going out and looking for students from these schools, as opposed to the tried and true schools, like Harvard, Yale, MIT in the Northeast, for example, the University of Michigan, other schools like that.

I think the other issue that we confront is that most of the research happens—begins at the lab stage, and a laboratory chemist, by and large, just doesn't appreciate, when they are handling very small quantities of material, what the impact of that looks like when we scale it up to commercial quantities. So there is kind of a view of, "Well, it is only a lab. How much can I—it is only a few hundred milliliters. It is only a pint of water. I am not generating that much waste." So I think we need to do a better job of educating the people in the laboratory, be it an industrial lab, be it an academic lab, be it a government lab. That lab-scale chemistry does count. And if it is successful, somebody is going to be using it in the commercial scale someday.

We have found that we have had to create programs of our own to train our scientists in green chemistry, because we are not having them show up on day one. We are starting to see now a flow of chemists trained in green chemistry, so I predict that will change. After all, green chemistry has only been around for a decade, and with any kind of a program, it takes about 10 years to start to get the yield in the investment.

We are also working very hard—diligently with schools in our area—in our R&D site areas to bring students in to let them understand what industrial chemistry looks like and how green chemistry can positively impact that, so when they go back to the universities, they can teach the faculties—tell the faculties, "Yes, industry is serious about this. They are anxious to see green chemistry practiced. And we better get about the job of teaching it in academia."

Mr. EHLERS. Dr. Gilman.

Dr. GILMAN. One of the reasons we—one of the first steps we took in trying to reshape our focus on sustainability was to introduce the P3 Award, largely for engineering schools, but that includes chemical engineering as well, was to begin to raise the level of awareness and interest. And I am very hopeful that next month we will be able to announce to you a collaborative effort we are doing to provide information on those schools, those graduate schools, that provide a focus in their curriculum on the sciences and technology associated with sustainability. So provide for interested students and really bring to the attention of the university administrators that there is an interest, and just rack up for folks, on a side-by-side basis, what curricula and what universities hold for people interested in this direction.

Mr. EHLERS. I am glad to hear that.

Dr. GINGREY. Dr. Ehlers, if we could, and I thank you, I think a vote has been called, and I did want to have time to recognize your colleague from Michigan and the Subcommittee Chairman of Research, Mr. Nick Smith.

Mr. SMITH. Thank you very much.

It seems to me that too often we sort of romance about the environmental benefits of regulations and other environmentally benign practices without regard to their impact on business and the economy. And so that is part of my question. That approach is short-sighted, especially in today's globally competitive environment, where even the most minor misguided regulation or requirement can put us at an enormous competitive disadvantage. And so that balance and that knowledge, and therefore, that adequate research is so important, and I think maybe part of—how much a role can government play? How much a role does good information play in stimulating the kind of green chemistry advances that can end up, like you suggested, Mr. Bradfield, in terms of making us more competitive, rather than less competitive? And so that would be on my—one of my questions.

And just to make a note of my second question, which is do we need better coordination between the four agencies that we are talking about to make sure that we are not overlapping, that we are not reinventing the wheel, and that we are working together in terms of the tax-dollar effort that government is playing. And I will stop there for a couple quick answers.

Dr. Bement.

Dr. BEMENT. Yes. And thank you, Mr. Smith. First of all, in answer to your first question, it is absolutely essential that we have a strong scientific basis for any regulations that we put out in this area. And if I can use my split personality, I see that as a role not only for the National Science Foundation, but also for the National Institute for Standards and Technology. NIST is very actively involved in developing the science base, and also the standards to support green chemistry in several dimensions.

With regard to your second question, of course there needs to be close interagency cooperation, and we need to build on the cooperation that currently exists.

Mr. SMITH. Any other comments? Mr. Bradfield.

Mr. BRADFIELD. Yes. Just two quick comments. We see a tremendous need for interagency coordination; even within the same agency sometimes, you can have conflicting rules that affect industry, one giving an incentive for green chemistry, the other, perhaps, giving you a disincentive for creating new materials.

The other thing I would say here is as a manager at Shaw and Vice-President, I am constantly green chemistry and sustainability. I have to sell up. I have to sell down. I have to sell out. And in order for—to do that, I need all of the help I can get, and if the Federal Government would interest my most senior management with tax credits that they know are going to push them a little bit more in that direction, they would be more inclined to be accepting of these projects where they are putting dollars at risk, then I can get more done.

Mr. SMITH. Thank you.

Dr. WOODHOUSE. I would like to pick up on your point about global competition and cut it the other way. It seems to me there is a danger of the U.S. losing out to the E.U. and other arenas. BASF and B.P., for example, have taken strategic choices to phase out chlorinated hydrocarbons, because they are worried about the long-term effect on their industry. Whether they phase them out over a decade, a generation, or a century, they haven't said, so we don't really know what is going on there.

But conversely, some of the U.S. companies are actually moving into markets that the Europeans are vacating. That is worrisome to me. I hate to see the U.S. lag rather than lead. And I—just from a purely commercial point of view, given the long lead time that is involved with major chemical facilities, if U.S. companies are not taking an aggressive stance towards green chemistry, and if the world continues to move, as I predict it will, towards the phase-out of the toxic chemicals, we are going to be caught behind. So that is the——

Mr. SMITH. So the bottom line—I mean, for lack of a better word, you—there is a golden mean on both ways——

Dr. WOODHOUSE. Absolutely.

Mr. SMITH.—that we need to work at, and hopefully it is going to be the green chemistry that is going to add for—add to our ability to be competitive in the most environmentally positive way.

Thank you, Mr. Chairman.

Mr. GINGREY. We—thank you, Mr. Smith.

We are rapidly running out of time, and I wanted to ask a quick question before we wrap up the hearing. And I am going to direct this mainly to Dr. Bement and Dr. Gilman. And actually, this is a two-part question. Do you think that the Nation might benefit from a more strategically focused, green chemistry R&D program? And are there adequate mechanisms by which agencies currently interact to determine strategies and priorities in green chemistry? Just quickly, Dr. Bement and Dr. Gilman.

Dr. BEMENT. I think that the program that we have is balanced in that it balances individual investigator grants with center grants. And the important thing about the center grants is that they also integrate public outreach, K through 12 outreach, and also curriculum development. So the program addresses a lot of the issues that have been raised during this hearing.

I think those programs have a natural growth potential right now. There is a lot of growing interest in these areas. All of these programs are growing, and they are distributed around the country, but obviously, it is something that needs to be nourished, nurtured, and continued to be encouraged.

Mr. GINGREY. And Dr. Gilman.

Dr. GILMAN. Our current extramural programs are well coordinated, I think, between the National Science Foundation and the EPA. To give it a more strategic focus, you probably need to bring to bear more agencies, and you probably need to bring to bear intramural work as well. EPA has both an intramural and an extramural research program. We have quite an extensive intramural program in pollution prevention and green chemistry. The effort is ongoing. As I said, we have a history of collaboration between agencies, especially on the extramural side. There are some efforts in the Office of Science & Technology Policy (OSTP) right now to try and make that a broader collaboration between agencies, Department of Energy, Department of Transportation, and the like. So we could do better at our coordination. We are trying to do better. And the levels of interaction are quite good, especially on the extramural side right now.

Mr. GINGREY. Thank you, Dr. Gilman.

And with that, we will wrap up this hearing. I want to thank all of the participants, each member of the panel, Dr. Bement, Dr. Gilman, Dr. Cue, Mr. Bradfield, Dr. Woodhouse, for your testimony. Unfortunately, we have to rush to make a quick vote, as my colleagues have already left, but I do thank you for your testimony, and of course, I really appreciate the unanimous support of H.R. 3970.

And with that, we will declare this hearing closed.

Thank you all very much.

[Whereupon, at 11:30 a.m., the Committee was adjourned.]

Appendix:

ADDITIONAL MATERIAL FOR THE RECORD

108TH CONGRESS
2D SESSION

H. R. 3970

To provide for the implementation of a Green Chemistry Research and Development Program, and for other purposes.

IN THE HOUSE OF REPRESENTATIVES

MARCH 16, 2004

Mr. GINGREY (for himself, Ms. EDDIE BERNICE JOHNSON of Texas, and Mr. EHLERS) introduced the following bill; which was referred to the Committee on Science

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A BILL

To provide for the implementation of a Green Chemistry Research and Development Program, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. SHORT TITLE.

This Act may be cited as the "Green Chemistry Research and Development Act of 2004".

SEC. 2. DEFINITIONS.

In this Act—

(1) the term "green chemistry" means chemistry and chemical engineering to design chemical

products and processes that reduce or eliminate the use or generation of hazardous substances;

(2) the term "Interagency Working Group" means the interagency working group established under section 3(c); and

(3) the term "Program" means the Green Chemistry Research and Development Program described in section 3.

SEC. 3. GREEN CHEMISTRY RESEARCH AND DEVELOPMENT PROGRAM.

(a) IN GENERAL.—The President shall establish a Green Chemistry Research and Development Program to promote and coordinate Federal green chemistry research, development, demonstration, education, and technology transfer activities.

(b) PROGRAM ACTIVITIES.—The activities of the Program shall be designed to—

(1) provide sustained support for green chemistry research, development, demonstration, education, and technology transfer through—

(A) merit-reviewed competitive grants to individual investigators and teams of investigators, including, to the extent practicable, young investigators, for research and development;

(B) merit-reviewed competitive grants to fund collaborative university-industry research and development partnerships;

(C) green chemistry research, development, demonstration, and technology transfer conducted at Federal laboratories; and

(D) to the extent practicable, encouragement of consideration of green chemistry in—

(i) the conduct of Federal chemical science and engineering research and development; and

(ii) the solicitation and evaluation of all proposals for chemical science and engineering research and development;

(2) examine methods by which the Federal Government can create incentives for consideration and use of green chemistry processes and products;

(3) facilitate the adoption of green chemistry innovations;

(4) expand education and training of undergraduate and graduate students in green chemistry science and engineering;

(5) collect and disseminate information on green chemistry research, development, and technology transfer, including information on—

(A) incentives and impediments to development and commercialization;

(B) accomplishments;

(C) best practices; and

(D) costs and benefits; and

(6) provide venues for outreach and dissemination of green chemistry advances such as symposia, forums, conferences, and written materials in collaboration with, as appropriate, industry, academia, scientific and professional societies, and other relevant groups.

(c) INTERAGENCY WORKING GROUP.—The President shall establish an Interagency Working Group, which shall include representatives from the National Science Foundation, the National Institute of Standards and Technology, the Department of Energy, the Environmental Protection Agency, and any other agency that the President may designate. The Director of the National Science Foundation and the Assistant Administrator for Research and Development of the Environmental Protection Agency shall serve as co-chairs of the Interagency Working Group. The Interagency Working Group shall oversee the planning, management, and coordination of the Program. The Interagency Working Group shall—

(1) establish goals and priorities for the Program, to the extent practicable in consultation with green chemistry researchers and potential end-users of green chemistry products and processes; and

(2) provide for interagency coordination, including budget coordination, of activities under the Program.

(d) REPORT TO CONGRESS.—Not later than 2 years after the date of enactment of this Act, the Interagency Working Group shall transmit a report to the Committee on Science of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate. This report shall include—

(1) a summary of federally funded green chemistry research, development, demonstration, education, and technology transfer activities, including the green chemistry budget for each of these activities; and

(2) an analysis of the progress made toward achieving the goals and priorities for the Program, and recommendations for future program activities.

SEC. 4. AUTHORIZATION OF APPROPRIATIONS.

(a) NATIONAL SCIENCE FOUNDATION.—From sums otherwise authorized to be appropriated, there are authorized to be appropriated to the National Science Foundation for carrying out this Act—

(1) $7,000,000 for fiscal year 2005;

(2) $7,500,000 for fiscal year 2006; and

(2) $8,000,000 for fiscal year 2007.

(b) NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY.—From sums otherwise authorized to be appropriated, there are authorized to be appropriated to the National Institute of Standards and Technology for carrying out this Act—

(1) $5,000,000 for fiscal year 2005;

(2) $5,500,000 for fiscal year 2006; and

(3) $6,000,000 for fiscal year 2007.

(c) DEPARTMENT OF ENERGY.—From sums otherwise authorized to be appropriated, there are authorized to be appropriated to the Department of Energy for carrying out this Act—

(1) $7,000,000 for fiscal year 2005;

(2) $7,500,000 for fiscal year 2006; and

(3) $8,000,000 for fiscal year 2007.

(d) ENVIRONMENTAL PROTECTION AGENCY.—From sums otherwise authorized to be appropriated, there are authorized to be appropriated to the Environmental Protection Agency for carrying out this Act—

(1) $7,000,000 for fiscal year 2005;

(2) $7,500,000 for fiscal year 2006; and

(3) $8,000,000 for fiscal year 2007.

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STATEMENT BY ARDEN BEMENT ON THE NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY'S GREEN CHEMISTRY ACTIVITIES

NIST's Measurements and Standards Are Key Enablers for Green Chemistry

NIST provides the measurements and standards that are essential for—development of green products and processes; industries to accurately assess their compliance with regulations; government agencies to ensure that environmental regulations are tenable and supportable by science based measurements.

NIST works directly with industry, government agencies and consensus standards organizations to facilitate the development of scientific measurement methods and standards that enable manufacturers test new products unequivocally for regulatory requirements. NIST is involved in advancing new technology development—in areas of energy such as fuel cells, in methods to minimize chemical waste and computational tools for assessing chemical efficiency of processes and life-cycle of products.

Examples of Impact of NIST's Research in Green Chemistry:

- **Green Solvents Processing:** NIST is making key property measurements and creating a web-accessible database on the properties of "green" solvents. Properties include measures of chemical stability, solubility, etc. for potential replacement candidates for environmentally hazardous chlorinated solvents; edible oils as alternative solvents for agricultural product preprocessing and stabilization; and studying ionic liquids as a class of solvents with good potential for "green processing."
- **Lead-Free Solder for Semiconductors:** The microelectronics industry estimates that the transition to lead-free solders in semiconductors is at least an order of magnitude more difficult than the elimination of chloroflurocarbons (CFCs). NIST research on materials and standards allowed for much faster implementation of processes leading to new lead-free products. Since the U.S. is transitioning to the relatively expensive but non-toxic lead-free solder, it is in the U.S.'s interest to promote lead-free solder standards internationally.
- **Fuel Cells Development:** NIST is developing a test protocol for residential fuel-cell systems, covering issues of efficiency, performance, and compatibility with the power grid for interconnection. The NIST Center for Neutron Research, the Nation's premier experimental neutron facility, utilizes neutron beams to image electrochemical processes inside fuel cells attracting the attention of major hydrogen fuel cell manufacturers.
- **Green Buildings Design:** NIST developed the BEES (Building for Environmental and Economic Sustainability) software, designed to explicitly help the construction industry select "green" building products that are cost-effective over their life-cycle. BEES measures environmental/health performance across all stages in the life of a product.
- **Alternative Refrigerants:** NIST enabled the transition from ozone-depleting CFCs to alternate refrigerants by providing a database of refrigeration properties of potential candidates. The database has been applied to problems of mixed refrigerant gases, and the mixtures of substances found in natural gas. It can potentially be extended for mixtures more typically found in fuel cell systems, and in hydrogen pipeline systems, especially converted natural gas pipelines. An economic assessment of this database (to provide U.S. industry with materials properties data, which enabled refrigerant and equipment manufacturers to comply with international agreements to phase out use of ozone-depleting chloroflurocarbons) indicated a benefit-cost ratio of 97 to 1.*
- **Standard Reference Materials for Sulphur in Fossil Fuel:** NIST produces a variety of well characterized materials known as Standard Reference Materials (SRM). The Sulphur SRMs are used to accurately determine the amount of unwanted Sulphur in fossil fuels. This is an area where large economic benefits can be expected from highly accurate measurements. An economic analysis of this program (to provide standard reference materials for measurement methods and validation, quality control, and instrument calibration needed by U.S. fossil fuel industries to reduce sulfur dioxide emissions) indicated a benefit-cost ratio of 113 to 1.*
- **Regulated Materials Data Exchange Standards:** NIST is coordinating the revision of the Interconnecting and Packaging Electronic Circuits (IPC) Prod-

uct Data eXchange (PDX) standards to include required materials declaration information. These standards are used for thousands of transactions monthly, and the revision under development will carry information such as the percent content of regulated materials, such as lead, mercury, cadmium, and hexavalent chromium.

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* *http://www.nist.gov/director/planning/strategicplanning.htm*

Additional Testimony in Support of
H.R. 3970, GREEN CHEMISTRY RESEARCH AND DEVELOPMENT ACT OF 2004

DR. J. MICHAEL FITZPATRICK
PRESIDENT AND CHIEF OPERATING OFFICER
ROHM AND HAAS COMPANY

Chairman Boehlert, Ranking Member Gordon, and Members of the Committee—thank you for inviting me to provide comments about the proposed *Green Chemistry Research and Development Act of 2004.* This legislation is a tremendous step forward in encouraging and advancing the continued discovery of green and sustainable technologies. Although a conflict prevented me from testifying in person at the hearing on March 17, my company feels strongly about this subject, and I plan to visit as many Committee Members as I can before the markup period closes to further discuss the benefits of this legislation.

I am the President and Chief Operating Officer of Rohm and Haas Company, one of the world's largest manufacturers of specialty chemicals. For nearly 100 years, our company has been in the business of discovering, developing, and manufacturing innovative materials that find their way into a wide range of major markets. Yet, most consumers have never heard of us because nearly everything we invent is used by other industries to make their products better, faster, stronger, and in many cases, more environmentally friendly. With perhaps the exception of Plexiglas®, which Rohm and Haas invented in the 1930s, and the Morton Salt brand, which we acquired in 1999, our products have gone largely unnoticed by the general public. Still, Rohm and Haas technology touches our lives in one way or another every day.

We are the world's largest manufacturer of acrylic monomer, and we pioneered the use of waterborne acrylic polymers in all kinds of coatings, from house and road-marking paints to water-based varnishes and paper coatings. We're a leader in developing environmentally friendly powder coatings that can replace alternatives based on solvent technology, and we offer a line of advanced, water-based automotive coatings designed especially for interior and exterior plastic parts in automobiles—a technology that gives car designers the ability to use more high performance plastics in their designs, thus lowering vehicle weight and increasing fuel efficiency. Recently, we introduced a new line of waterborne acrylic emulsion polymers that can replace formaldehyde in household insulation.

Our process chemicals can be found in a wide range of applications, from unique ion exchange resins that purify everything from water to new classes of pharmaceuticals, to biocides that control the growth of harmful bacteria in personal care products.

Our research and development in electronic materials is world class, with a broad set of products used by top semiconductor manufacturers worldwide. Our photoresist chemicals are used to replicate minute circuitry patterns on silicon wafers, and our planarization technology polishes these wafers to a mirror finish, a critical step in smaller and more powerful semiconductors. Our "embedded" circuit board technology places resistors and capacitors *within* a circuit board instead of on top of it, enabling smaller and smaller cell phones, PDAs, and other portable electronic devices.

Many of Rohm and Haas's water-based adhesives continue to find use in hundreds of applications, from caulks and sealants, to construction adhesives and laminates. Our new cold seal technology is used in food packaging, where traditional heat sealing would be undesirable.

Our company employs more than 17,000 people and recorded over $6.4 billion in sales last year. We operate more than 100 research and manufacturing facilities in 25 countries. Our headquarters is located on historic Independence Mall in Philadelphia, Pennsylvania, just a few blocks away from our original offices established in 1909 by founders Otto Röhm and Otto Haas. And while we have changed, adapted, and of course grown since those early years, we retain a strong and unambiguous thread to the values that our founders imparted on the organization: concern for our employees, the neighbors where we operate, and our customers. We strive to ensure Rohm and Haas operations and products meet the needs of the present global community without compromising the needs of future generations. At Rohm and Haas, we work hard to integrate economic growth, environmental protection, and social responsibility as important considerations in our business decisions.

I joined Rohm and Haas in 1975 as a senior scientist following my two years as a National Institutes of Health postdoctoral fellow at Harvard University. My first five years were spent in the laboratory, developing new agricultural products at our company's main research campus in Spring House, Pennsylvania, about 20 miles outside of Philadelphia. Although my career took a turn toward marketing and business following that initial assignment, I have always had a passion for the creativity, the excitement and the spirit of innovation. To take an idea, research it, and develop it into a product from basic chemical building blocks—a product with unique and sometimes amazing properties—and to see that product improve life, or enhance the broader society in some way, is the joy of every industrial chemist.

I returned to my technology roots in 1993 as Director of Research for Rohm and Haas. Although I never made it back into the lab, I nonetheless retain a strong relationship to the technology and research side of our industry. I understand the daily challenges facing researchers: the demands for greater research efficiency, the requirements that an innovation meet multiple safety, efficacy, risk, and environmental expectations, and that it's marketable at a fair price with sustainable returns.

It is because of my unique career history and my passion for this subject that I feel especially honored to comment on the benefits of the *Green Chemistry Research and Development Act of 2004.* In fact, I have been an active and vocal advocate for green and sustainable chemistry for nearly 20 years. I am a board member of the Green Chemistry Institute, and have authored and presented numerous papers and presentations on green and sustainable chemistry in a variety of publications and venues around the world. I am proud to work for a company that has been recognized for its research and development of environmentally friendly, game changing technologies, some of which have completely altered the landscape in certain markets.

Since the early 1990s, Rohm and Haas has been recognized for its "green" technology by the World Environment Center, the U.S. Environmental Protection Agency (EPA), and the U.S. Department of Energy (DOE), to name a few. We were the first company to be honored with two Presidential Green Chemistry Challenge Awards, the first for a novel pesticide that mimics a hormone in a particularly destructive caterpillar, causing it to stop feeding, and eventually starving to death. Best of all, the pesticide has no ill effects on other beneficial insects. We were recognized again for our family of Sea-Nine® antifouling biocides, which replaced other products containing tri-butyl tin. Sea-Nine® safely keeps barnacles and other sea creatures from attaching themselves to ship hulls. A smooth hull means less drag, which translates into huge fuel savings over thousands of nautical miles.

Rohm and Haas was practicing green chemistry before anyone thought to label such an endeavor when, in the 1950s, we were the first company to introduce water-based acrylic polymers used as binders in house paint. Alkyds and other solvent-based paints—with their high VOC emissions and difficulty to apply and clean-up—were the predominant paint technology at the time. Despite a slow beginning and initial resistance, our researchers remained committed to bringing not only an environmentally friendly alternative to the paint industry, but an alternative that actually performed significantly better than the solvent and oil-based technologies. Our perseverance paid off and helped spark the birth of modern acrylic latex paints. Today, 85 percent of paints, stains, and primers purchased by home owners (the Do-It-Yourself market) use waterborne technology.

Although this technology recently celebrated its 50th anniversary, we continue to build and improve upon our acrylic platform. We expect to soon begin work on new low VOC coatings using sustainable chemistries, exciting research I'll describe in more detail shortly.

During the past 15 years, Rohm and Haas Company has joined, has been a signatory to, or has reaffirmed its support of numerous voluntary programs, including: EPA's 33/50 emissions reduction program, the International Chamber of Commerce charter on Sustainable Development, the Pew Center on Global Climate Change Business Environmental Leadership Council, the Executive Council of the World Business Council for Sustainable Development, the U.S. Department of Energy's Industries of the Future Allied Partner program, and the U.S. Council on Sustainable Development. We have held various symposiums for our employees, including a two-day "Innovating for Sustainability" conference for company researchers. This event presented some of the latest green innovations from a broad spectrum of experts, including Wolfgang Holderich and Malcolm Willis, widely recognized as the authors of green chemistry.

Our company's commitment to green and sustainable chemistry begins with its leadership. In 2002, our Board of Directors renamed the Corporate Responsibility and Environment, Health, and Safety Committee to the Committee on Sustainable

Development, and adopted a new charter for its work. This move has helped us further integrate the principles of green chemistry throughout our company.

Collaboration is Key

During the last several years, environmental, social, and economic forces have transformed green and sustainable chemistry from merely a secondary consideration into a core objective of nearly every responsible company in nearly every industry. Today, before a new chemical compound is synthesized or a new product is designed, chemists and engineers step back to look holistically at the short- and long-range impact of their innovations. They question the type of raw materials used. They assess whether safer alternatives are available. They investigate novel manufacturing methods, and look for ways to reduce or eliminate dangerous byproducts. They consider inherent risks of the new product—risks to workers, communities, and end users—and how they can be mitigated or completely avoided.

Although you will find these activities underway daily in Rohm and Haas labs and production plants around the world—and in the labs and plants of other responsible companies—it is by no means easy. Significant resources are required to develop, analyze, and test alternative raw materials or brand new chemistries. This can lead to the study of thousands of different compounds and formulations. When a promising material is identified, a fresh round of analysis begins to ensure it meets strict environmental, risk, economic, and performance expectations. To do this successfully, I believe industrial research initiatives must turn to broad collaboration with multiple external partners.

Innovations that incorporate green chemistry will emerge and develop far more quickly when industry works together with government, academia, and even nongovernmental organizations (NGOs, such as environmental or consumer groups) to address common goals. In recent years, we have seen many tremendous examples of two or more of these groups joining forces to develop commercially successful green step-out innovations. The collaboration has paid off handsomely for my industry, for the industries we serve, and certainly for society as a whole. Let me offer a few examples.

The automotive industry may be one of the most visible stories today that illustrates my point. Within the last three to five years, we have witnessed dramatic changes in new sources of fuels and alternative propulsion methods—many still under development, but some commercialized and in use today. As governments around the world raise fuel economy standards in an attempt to curb greenhouse gasses, some of the largest automobile companies are rolling out cars that can achieve two or three times the fuel efficiency versus cars operating with traditional internal combustion engines. Today, so-called hybrid vehicles appear to be catching on with automakers and consumers alike. While these ultra efficient automobiles have gained momentum—to a certain degree from pressure from NGOs and governments—industry has clearly benefited from multiple government funding sources that have encouraged step-out scientific research on cleaner burning, more efficient modes of transportation.

Today, Toyota and Honda are selling tens of thousands of these hybrids, which use a large battery recharged by a smaller-than-normal gas engine and by collecting energy when the brakes are applied. The electric motor assists the vehicle during heavy acceleration or at very slow speeds, depending on the technology. By mid-decade, Japanese automakers plan to sell hundreds of thousands of hybrid cars. American car manufacturers are a step or two behind their Japanese counterparts, but are also working on this technology.

Many believe this represents the beginning of large scale changes in the automotive industry, the first significant change since a gasoline-powered Oldsmobile gained popularity in 1903, making steam-powered vehicles obsolete. And for the chemical industry, this change represents both opportunities and challenges. Fundamental shifts in automotive technologies spell changes for our product offerings. New advanced control and electronic systems, lighter and stronger materials, and new paint and coating technologies that adhere to and protect composite parts, are just a few of the opportunities where advanced green chemistry can play a role. At Rohm and Haas, in collaboration with our JV partner, Nippon Paint, we continue to develop advanced, environmentally friendly waterborne coatings that protect plastic auto parts. These coatings are critically important as plastic parts become thinner and lighter.

We are aggressively working on a new generation of automotive coatings that use our dry powder technology, virtually eliminating all volatile organic compounds. This illustrates how opportunities can be uncovered at the interface of seemingly unrelated entities: in this example, we have ever increasing laws calling for more efficient automobiles, we have manufacturers meeting their efficiency goals by using lighter, stronger plastic in cars, and we have our water-based coating technology that eliminates harmful solvents and provides superior protection to plastic parts.

Another challenge for the automotive industry is to ensure that chemistries meet recyclability guidelines, since many regulations today, particularly throughout Europe, require automobile components to be recycled or reusable. In a wonderful example of collaboration, The Dow Chemical Company and Mitsui Chemicals met this challenge head-on when they agreed to jointly develop a new block copolymer featuring properties of two resins that will make stronger car bumpers. Not only will these high-strength bumpers require less resin to manufacture, but if this new product takes the place of traditional metal parts, it will help reduce a car's overall weight, which of course translates into better fuel economy. Best yet, this new resin can be recycled as an adhesive to hold other plastic parts together.

As I am sure Members of this committee are well aware, hybrid vehicles are just the first step in a giant leap toward even more impressive green and sustainable technology. Fuel cells that use hydrogen and oxygen to create electric power have received widespread attention in the media, and for good reason. Generating only heat and water as its byproduct, this technology is seen by governments around world (including our own), by NGOs, and by many others as a potential number-one breakthrough in transportation power. Companies, universities, and private laboratories are working on fuel cell technology, and through grants and incentive programs, governments are collaborating with industry to see this technology come to fruition. I understand that General Motors has 600 researchers working on fuel cell technology in the U.S. and Germany, and has worked with Germany's top safety institute, TÜV, to ensure their system meets strict European standards. This is another example where industry and government or quasi-government agencies, working together, are bringing sustainable technology from the lab bench to the consumer.

Closer to the chemical industry, one doesn't have to look very far to find examples of where we can work closely with the government on green and sustainable technologies. The DOE launched a program to help fund companies conducting biomass research and development for the production of sustainable products. At Rohm and Haas, we were pleased when the DOE enacted its Allied Partner program, which offers not only funding opportunities for new technologies, but also access to DOE research and data.

Success stories are not limited to collaboration between government and industry. There are tremendous examples of industry, government, and academic groups pooling their collective know-how to deliver stellar technology with a promising future. A consortium of Deere & Company, Diversa, duPont, Michigan State University, and the National Renewable Energy Laboratory received nearly $20 million from the DOE to develop a "bio refinery" that produces ethanol and other chemicals derived from corn.

There are many more example of broad collaboration outside the United States. Italy's National inter-university consortium of chemistry for the environment in Venice launched an annual recognition program for contributions to clean chemical processes. In Melbourne, the Royal Australian Chemical Institute has held its Green Chemistry Challenge Award since 1999. And in the United Kingdom, the Royal Society of Chemistry in London launched the Green Chemistry Network. Headquartered at the University of York, the 600-member network helps chemical companies and scientists share best practices, promotes the sharing of green technologies, and offers data supporting the cost benefits of green science.

In another notable example of green chemistry collaboration in England, chemistry professors looking for the right connections with industry can turn to the Crystal Faraday Partnership, a virtual green chemistry center. Jointly developed by the Royal Society of Chemistry, the Chemical Industries Association in London, and the Institution of Chemical Engineers, this group is a collaborative conduit, linking the creative spirit and technical expertise of pure researchers with the financial support and manufacturing resources of a corporation. In one example I often cite, the Nottingham University chemistry department developed a series of unique supercritical fluid reactions, and through the Crystal Faraday Partnership, collaborated with fine chemicals firm Thomas Swan to use these reactions in a variety of processes. The new technology replaces conventional solvents with inert supercritical fluids in key processes, leading to reduced or eliminated wastes and undesirable byproducts.

Would Thomas Swan use this new technology today if the collaborative community established by the Royal Society of Chemistry did not exist? Perhaps. But there is no denying that the Crystal Faraday Partnership and similar organizations that support and encourage cooperation—often across disparate groups—is a crucial tool and proven commodity that helps speed the pace of green innovation at companies around the world.

Before moving on, let me touch on another group—the non governmental organizations, or NGOs—that has collaborated with industry to develop green chemistry.

Admittedly, the image of these two very different entities holding hands and working toward a common goal is not one to which we're accustomed. Suffice it so say that industry and many environmental and consumer groups have not in the past seen eye to eye. Nevertheless, that is beginning to change—slowly, cautiously—but progress can be seen if you look hard enough.

Nineteen eighty-seven was the year some say we first saw a glimpse of cooperation between industry and environmental groups, at least as it relates to sustainability. That's the year the United Nations published its report, "Our Common Future," in which the most frequently quoted definition of sustainable development is still cited today. It reads:

> "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

This statement marked the recognition by environmental groups that economic growth and development were necessary to meet the needs of the world's expanding population. It also signaled the philosophical acceptance by industry that growth must be accomplished in a way that meets the needs of today's society AND preserves natural resources and the environment for future generations.

Examples of close working relationships between companies and environmental groups are hard to come by, to be certain. But when these groups join forces, the results can be impressive. For example, in the late 1990s, the World Wildlife Fund and Unilever joined forces to start the Marine Stewardship Council. Now an independent non-profit organization, this council offered one of the first "eco-labels" to identify fish certified to come from an environmentally sustainable catch. This was a perfect match for Unilever, considering that its Bestfoods division manufactures fish sticks and other frozen seafood products.

There are literally hundreds of opportunities for chemical companies to accelerate our pace toward Green and Sustainable Chemistry through powerful collaboration and partnerships. Is it easy? No. . .it takes work, extra effort, and relationship building. And let's be honest—companies that develop new and successful technologies may be inclined to use it as competitive advantage rather than share it with competitors. That's a risk/benefit balance that responsible companies must weigh at some point. One thing is certain, however: The speed in which today's market demands new chemistries, better processes, and greener products is accelerating. Bringing green chemistry out of the labs and into the marketplace faster will require the kind of collaboration I have just described. And it will require funding and support.

"The Green Chemistry Research and Development Act of 2004" Will Help Accelerate Pace of Green and Sustainable Innovation

Many of the examples I described included one form or another of government or quasi-government agency support, either through funding, access to National Labs' data, or assistance in knowledge transfer. The role of collaborative support in green and sustainable chemistry research cannot be understated.

As I am sure Committee Members are well aware, the $460 billion chemical industry, a key element to our nation's economy that accounts for 10 cents out of every dollar in U.S. exports, is coping with an unprecedented energy crisis. Volatile, runaway natural gas prices have steadily eroded our ability to compete in an industry that continues to see an influx of very competent, competitive chemical manufactures from Europe, Asia, and the Middle East. Current natural gas prices have turned U.S. chemical manufactures into the world's high cost producer. This in turn has had a profound impact on our profitability, and subsequently, our capacity to raise (or even maintain) expensive R&D budgets.

Although chemical companies invest more in research and development than any other business sector, there are disturbing signs that this trend is slipping. In a recent survey conducted by *Chemical and Engineering News,* a respected industry publication, only seven out of 17 companies surveyed expected to increase their R&D spending in 2004. Six plan no increases, while four plan cutbacks in their R&D budget. According to the survey, 2004 R&D as a percent of sales—a widely used barometer to indicate a company's relative commitment to research, will fall to an estimated decade low of 3.2 percent. This is considerably below the decade high of five percent in 1994 and two tenths of a percent less compared to last year's average.

The upshot? External funding for green chemistry—no matter the size and the source—cannot come at a better time for an industry that is grappling with historically high energy and raw material prices, squeezed margins, and fierce competition from companies outside of our boarders.

At Rohm and Haas, we recognized the need to bolster our collaborative skills and external funding capabilities about two years ago. We conducted a day-long workshop with our top research leaders to teach them about the skill, and the art, of finding external collaborative partners. Emerging from that seminar was the creation of our Technology Partnerships group, which assists our scientists with matching their projects with potential external funding opportunities. This effort has yielded promising results.

One example is the work I mentioned earlier about new low VOC coatings using sustainable chemistries. Last year, Rohm and Haas submitted a proposal for a DOE cooperative grant to research and develop new polymer technologies that can remove as much as 30 percent of raw materials from the polymer particles in an acrylic emulsion, a key ingredient in paint. Working together with Archer Daniels Midland (ADM), the University of Minnesota, and the DOE, Rohm and Haas plans to match its novel binders with new, renewable plant-based coalescing agents from ADM to deliver breakthrough coatings that offer outstanding performance, environmental friendliness, and cost efficiency. When fully deployed, this new technology is expected to save up to 86 trillion BTUs per year. We hope to hear good news about our proposal soon from the DOE!

This is precisely the type of collaboration that can accelerate critical green chemistry research, and illustrates why the *Green Chemistry Research and Development Act of 2004* is such an important bill. In addition to funding support, which more and more chemical companies, including my own, are seeking to supplement tightening R&D budgets, this Act encourages technology transfer between key stakeholders. Collaboration between industry, government, academia, and even NGOs, is a promising trend in research that has proven its worth, and is poised to increase in the coming years. This bill will encourage and accelerate that movement.

While the bill's research funding component may be, understandably, the most visible and sought after benefit, other activities included in the proposed legislation are equally important. The Federal Government's encouragement of green chemistry research—using incentives and other levers—and its power to promote the adoption and commercial application of green chemistry innovations, can exert great influence on the direction of these endeavors. This is especially important, since recent history has shown us that consumers are not going to pay more simply because a product is labeled "green," or was developed using green chemistry processes.

Although "green" by itself typically is not a compelling selling point, more consumers today are taking a second look when green products demonstrate real (or sometimes perceived) value. Chances of successfully marketing these products increase dramatically when we can demonstrate increased performance, long-term energy savings, or other tangible benefits for the consumer.

For example, U.S. commercial and residential housing are responsible for more than 36 percent of our country's energy consumption, and yet, the success of green marketing in that industry has varied widely. On the commercial side, marketing super efficient office buildings has been met with limited success beyond baseline standards set by the EPA's Energy Star program. The return on premium costs associated with high efficiency commercial construction cannot be realized unless property developers and owners hold their buildings long enough to reap utility savings. And since turnover in commercial property ownership is commonplace, green marketing in this segment is not particularly successful.

On the other hand, the story is much more positive in residential housing, where encouragement from NGOs and the prospects of lower energy bills (the *"real value"* I mentioned earlier) have resurrected interest in "green" homes. Spurred by consumers' interest in smaller monthly utility bills, U.S. builders are marketing environmental friendly features that were unheard of in homes five or 10 years ago. Porous driveways that allow rainwater to settle back into the ground and tankless hot water heaters, common throughout many parts of Europe and Japan but fairly new in the U.S., can save up to 50 percent in energy bills. Energy efficient "low E" double pane windows, heating systems approaching 90 percent or better efficiency, and appliances that use 50 percent less energy versus those in the 1970s are now widely available. Hard wood flooring continues to loose market share to carpeting and laminates from recycled materials, a shift that has reduced our reliance on diminishing lumber supplies.

Although some of these examples are not related to green chemistry per se, they do illustrate that green products can attract consumers' attention as long as the products offer value with a clear payoff. Encouragement from this proposed legislation to adopt and use products that are developed from green chemistry is a positive step in marketing the virtues of green technology.

The bill's provision to "promote the education and training of undergraduate and graduate students in green chemistry science and engineering," is another welcome component. As chemical companies ramp-up their green and sustainable chemistry research, the need for new technical talent who can hit the ground running with the right chemistry skills and proper mindset attuned to green technology is a winning combination. There are many companies, including my own, who have established special labs that focus on next generation sustainable technologies. At Rohm and Haas, our Green Chemistry Laboratory uses the 12 Principles of Green Chemistry as a framework to focus on green opportunities without taking our eyes off of market realities. As these types of labs increase in number and size, chemists and engineering graduates with unique green chemistry skills will be in high demand.

Finally, I do not want to short change provisions of the bill that call for the collection and dissemination of information on green chemistry research, and the development of outreach venues that support knowledge transfer. It is difficult to quantify, but I can tell you from first hand experience that the tools supporting best practice sharing—conferences, symposiums, electronic forums and databases, written materials—are critically important to the advancement of green and sustainable chemistry. Bringing great minds together, no matter the method, is a force multiplier for diverse thought and new solutions to old problems.

On behalf of Rohm and Haas Company, I strongly support the *Green Chemistry Research and Development Act of 2004.* This legislation provides funding that is crucial, more so today than in recent times, to accelerate green research and development endeavors. Provisions that develop future chemistry and engineering talent, and foster collaboration and the transfer of best practices, are important catalysts that will advance new technologies based on sound, responsible science and the principles of green and sustainable chemistry.

STATEMENT IN SUPPORT OF H.R. 3970 BY DR. J. MICHAEL FITZPATRICK, PRESIDENT AND CHIEF OPERATING OFFICER, ROHM AND HAAS COMPANY

On behalf of the Rohm and Haas Company, I want to offer our support for the proposed *Green Chemistry Research and Development Act of 2004.*

Within the last decade, environmental, social, and economic forces have transformed green and sustainable chemistry from merely a secondary consideration into a core objective of nearly every responsible company in nearly every industry. Today, before a new chemical compound is synthesized or a new product is designed, chemists and engineers step back to look holistically at the short- and long-range impact of their innovations. They question the type of raw materials used, and whether safer alternatives are available. They investigate novel manufacturing methods, and look for ways to reduce or eliminate dangerous byproducts. They consider inherent risks of the new product—risks to workers, communities, and end users—and how they can be minimized or completely avoided.

Although you will find these activities underway daily in Rohm and Haas labs and production plants around the world—and in the labs and plants of other responsible companies—it is by no means easy. Significant resources are required to develop and test alternatives or brand new chemistries, and to ensure they meet strict environmental, risk, economic, and performance expectations. To do this successfully, we believe broad collaboration is not only prudent, but necessary.

Innovations that incorporate green chemistry will emerge and develop far more quickly when government, industry, academia, and even non-governmental organizations (environmental or consumer groups) work together to address common goals. In the last few years, we have seen many tremendous examples of two or more of these groups joining forces to develop commercially successful “green” step-out innovations. But much more can be done.

With U.S. chemical companies facing record breaking energy and raw material prices, one cannot understate the importance of differentiated technology based on the principles of green chemistry. Rohm and Haas Company believes the proposed *Green Chemistry Research and Development Act of 2004,* and its associated funding, will provide strong support and encouragement for additional collaboration, knowledge transfer, and crucial research on a new class of green and sustainable technologies.

About Rohm and Haas Company

About Rohm and Haas: Rohm and Haas is a worldwide producer of specialty chemicals with more than 100 plants and research facilities in 26 countries. Rohm and Haas technology is found in paint and coatings, adhesives and sealants, construction materials, personal computers and electronic components, household cleaning products and thousands of everyday products. Additional information about Rohm and Haas can be found at *www.rohmhaas.com.*

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March 25, 2004

Hon. Sherwood Boehlert
House of Representatives
Washington, DC 20510

Dear Mr. Boehlert,

I am writing to support the Green Chemistry Research and Development Act of 2004.

As you probably are aware, Genencor and DuPont were the recipients of the President's Green Chemistry Award last year for our collaboration on a bioderived polymer called Sorona™. That product starts with corn starch as a raw material to produce a polymer that has special properties that make it a very desirable product for making new fibers for carpets, performance fabrics and molded plastics. The product cannot be economically made from fossil fuel.

But more importantly, the product is one of the first potential high-value products that can be produced in a "biorefinery" that uses renewable raw materials for the production of chemicals, fuels and materials. The biobased economy that will emerge as biorefineries take their place alongside oil refineries should improve the environmental profile of many industrial sectors.

Furthermore, the application of biocatalysts and bioprocesses in industrial processes generally reduces the environmental footprint of any given process. This improved performance has been amply reported by the OECD in their study: "The Application of Biotechnology to Industrial Sustainability" and by the National Research Council's report: "Biobased Industrial Products". The OECD report highlights 21 case studies of the environmental gains from using enzymes to replace other traditional catalytic steps in a variety of settings.

The Green Chemistry Research and Development Act of 2004 should accelerate the adoption of green chemistry in the marketplace. Thank you for your support of this important initiative.

Sincerely,

cc: Hon. David Garmen, Assistant Secretary for EERE, DOE
Douglas Kaempf, Biomass Program Manager, DOE
Brent Erickson, vice president, BIO

AMERICAN CHEMICAL SOCIETY
NEWS
SCIENCE THAT MATTERS

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FOR IMMEDIATE RELEASE

World's largest scientific society backs green chemistry bill

The American Chemical Society today strongly supported the *Green Chemistry Research and Development Act of 2004*, introduced March 16, which will advance federal coordination, dissemination, and investment in green chemistry research and development.

"As real environmental progress shifts from controlling and cleaning up pollution to preventing it in the first place, more innovative strategies and technologies will be essential," according to ACS President Charles Casey. "Green chemistry plays a critical role because it literally seeks to change the equation by designing cleaner and safer chemicals, products and processes up front — which goes to the heart of pollution prevention."

Casey, in a letter to Rep. Phil Gingrey (R-Ga.), main sponsor of the Green Chemistry Research and Development Act of 2004, praises an interagency program set up by the legislation. The letter coincides with a March 17 House Science Committee hearing on the bill.

Under the bill, the National Institute of Standards and Technology, the National Science Foundation, the Environmental Protection Agency and the Department of Energy would work together to enhance funding and coordination of green chemistry R&D. The interagency program would support merit-reviewed grants to individual researchers; university-industry partnerships; R&D and technology transfer at federal laboratories; and the education and training of undergraduate and graduate students in green chemistry science and engineering.

– more –

A nonprofit organization with a membership of more than 159,000 chemists and chemical engineers, the American Chemical Society publishes scientific journals and databases, convenes major research conferences, and provides educational, science policy and career programs in chemistry. Its main offices are in Washington, D.C., and Columbus, Ohio

According to Casey, "green chemistry technologies have eliminated waste, improved safety and saved industry money. The manufacture of plastics from renewable feedstocks, the redesign of pharmaceutical synthesis to reduce waste, and the development of catalysts that improve energy efficiency show that these technologies can be environmentally and economically viable." But, he adds, "substantial scientific and engineering challenges remain and more long-term R&D in this area is badly needed."

The ACS, the world's largest scientific society, with its Green Chemistry Institute, has played a leading role in advancing the concept of improving the environment through chemistry.

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#13685 Released 03/17/2004

STATEMENT BY THE AMERICAN CHEMISTRY COUNCIL

AMERICAN CHEMISTRY COUNCIL SUPPORTS COORDINATED FEDERAL GREEN CHEMISTRY R&D PROGRAM

The American Chemistry Council (ACC) supports the establishment of an interagency research and development program to coordinate federal green chemistry R&D, such as efforts outlined in the *Green Chemistry Research and Development Act of 2004.* A coordinated approach would increase efficiency and help identify appropriate goals for a federal green chemistry R&D program.

Green chemistry looks at the life cycle of chemical products—benefits, sustainability, potential risks and other attributes—to help develop products that bring value to society while reducing environmental impact.

Chemical makers fully recognize the benefits of R&D. In fact, the business of chemistry spends more on R&D than any other private sector. Chemical makers share a common interest with the Federal Government in conducting research that leads to the development of alternatives or new chemistries, while meeting strict environmental, risk, economic and performance expectations.

While R&D often is an inviting target for budget reductions in the private and public sectors, the Federal Government should focus on making R&D programs more productive. Despite the difficult economic conditions in the industry and efforts by many companies to reduce spending, chemical makers have become more efficient users of R&D dollars by reducing bureaucracy, thereby retaining researchers at the bench who generate the new concepts and ideas that ultimately enrich the future for all Americans and the world.

http://www.accnewsmedia.com

The American Chemistry Council (ACC) represents the leading companies engaged in the business of chemistry. ACC members apply the science of chemistry to make innovative products and services that make people's lives better, healthier and safer. ACC is committed to improved environmental, health and safety performance through Responsible Care, common sense advocacy designed to address major public policy issues, and health and environmental research and product testing. The business of chemistry is a $460 billion enterprise and a key element of the Nation's economy. It is the Nation's largest exporter, accounting for ten cents out of every dollar in U.S. exports. Chemistry companies invest more in research and development than any other business sector. Safety and security have always been primary concerns of ACC members, and they have intensified their efforts, working closely with government agencies to improve security and to defend against any threat to the Nation's critical infrastructure.